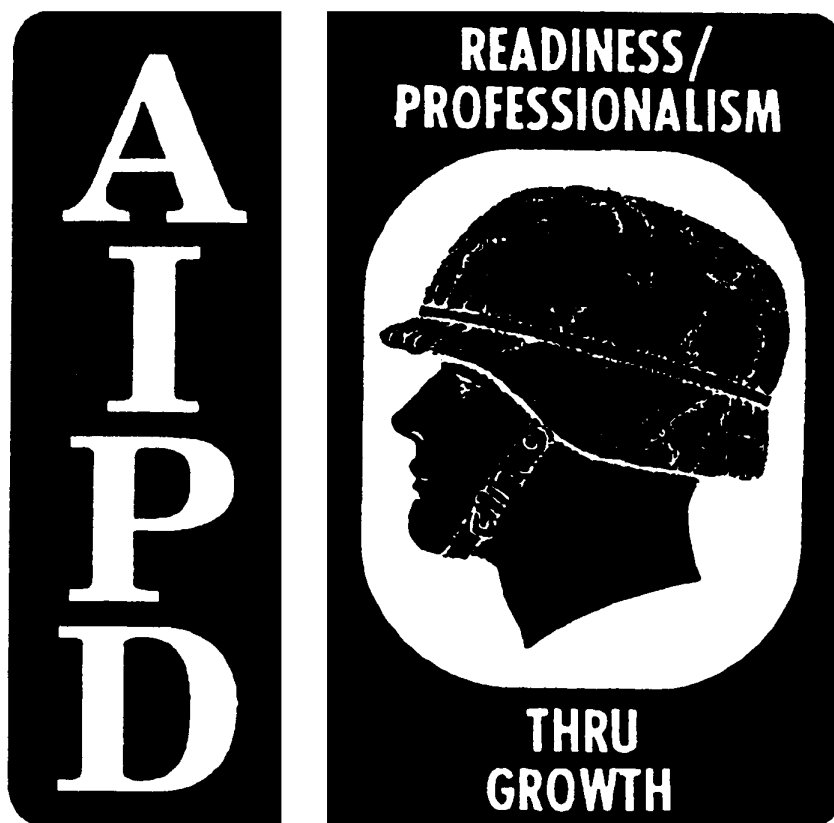
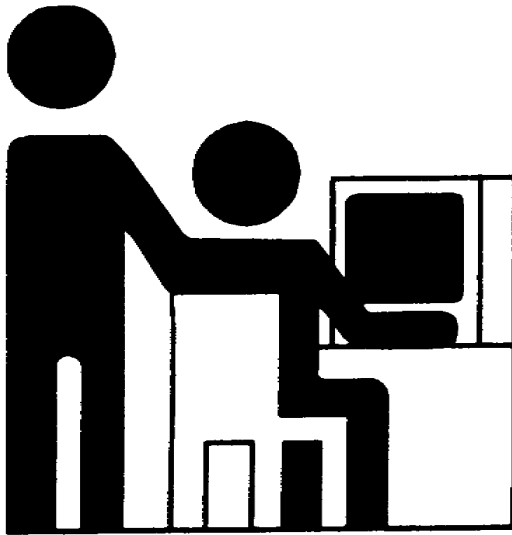

LATHE OPERATIONS



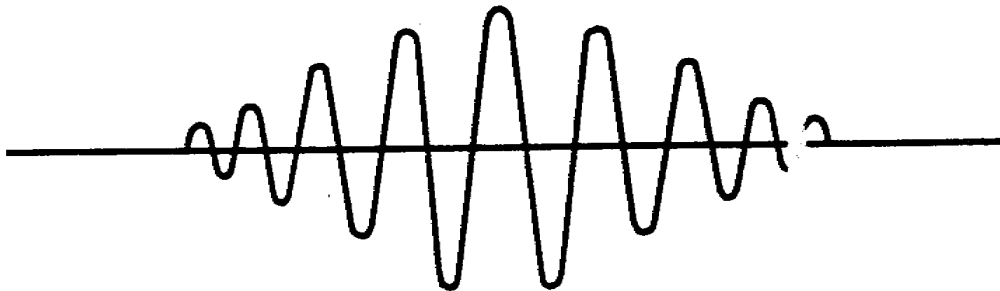
**THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM**



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US ARMY REPAIR SHOP TECHNICIAN
WARRANT OFFICER ADVANCED CORRESPONDENCE COURSE

MOS/SKILL LEVEL: 441A

LATHE OPERATIONS

SUBCOURSE NO. OD1645
EDITION 8
US Army Correspondence
Course Program

7 Credit Hours
NEW: 1988

GENERAL

The purpose of this subcourse is to introduce the uses of the lathe, to include safety; the uses, repair and adjustment of lathe attachments; and the various thread forms, uses, calculations and machining techniques.

Seven credit hours are awarded for successful completion of this subcourse. It consists of one lesson divided into three tasks.

Lesson 1: THE LATHE USES AND SAFETY; USES, REPAIR, AND ADJUSTMENT OF LATHE ATTACHMENTS; AND VARIOUS THREAD FORMS, USES, CALCULATIONS, AND MACHINING TECHNIQUES

TASK 1: Describe the uses of the lathe, to include safety.

TASK 2: Describe the uses, repair, and adjustment of lathe attachments.

TASK 3: Describe the various thread forms, uses, calculations, and machining techniques.

LATHE OPERATIONS - OD1645

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***** IMPORTANT NOTICE *****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 1

LESSON 1

THE LATHE USES AND SAFETY; USES, REPAIR, AND
ADJUSTMENT OF LATHE ATTACHMENTS; AND VARIOUS
THREAD FORMS, USES, CALCULATIONS, AND
MACHINING TECHNIQUES

TASK 1. Describe the uses of the lathe, to include safety.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within three hours

REFERENCES

No supplementary references are needed for this task.

1. Introduction

Lathes were developed as early as the 15th century and were known as "bow" lathes. The operator rotated the workpiece by drawing a bow back and forth, either by hand or with the use of a foot treadle. Next came Bessons lathe in 1568, which was driven by a cord passing over a pulley above the machine. This in turn drove two other pulleys on the same shaft which rotated the workpiece and a crude, wooden lead screw, which in turn allowed the operator to remove metal from the piece being machined. The screw cutting lathe originates in the 17th century. Development and advancements have continued and today we have sophisticated computerized controlled lathes.

Lathes have allowed man to reshape, machine and manufacture many precision cylindrical components made of various types of metal, wood, plastics, and other materials. Without the lathe, man would still be trying to produce cylindrical components

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 1

in some crude fashion or another. However, because of advanced technology, the lathe has allowed man to become an important asset in developing and machining many precision components needed to operate and function in many areas of our industrial complex.

2. Lathes Types and Uses.

a. *General.* The lathe is a machine tool used principally for shaping articles of metal, wood, or other material. All lathes, except the vertical turret type, have one thing in common for all usual machining operations; the workpiece is held and rotated around a horizontal axis while being formed to size and shape by a cutting tool. The cutter bit is held either by hand or by a mechanical holder, then applied to the workpiece. Principal capabilities of the lathe are forming straight, tapered, or irregularly outlined cylinders, facing or radial turning cylindrical sections, cutting screw threads, and boring or enlarging internal diameters. The typical lathe provides a variety of rotating speeds and suitable manual and automatic controls for moving the cutting tool.

b. *Types of Lathes.* Lathes can be conveniently classified as engine lathes, turret lathes, and special purpose lathes. All engine lathes and most turret and special purpose lathes have horizontal spindles and, for that reason, are sometimes referred to as horizontal lathes. The smaller lathes in all classes may be classified as bench lathes or floor or pedestal lathes, the reference in this case being to the means of support.

c. *Engine Lathes.*

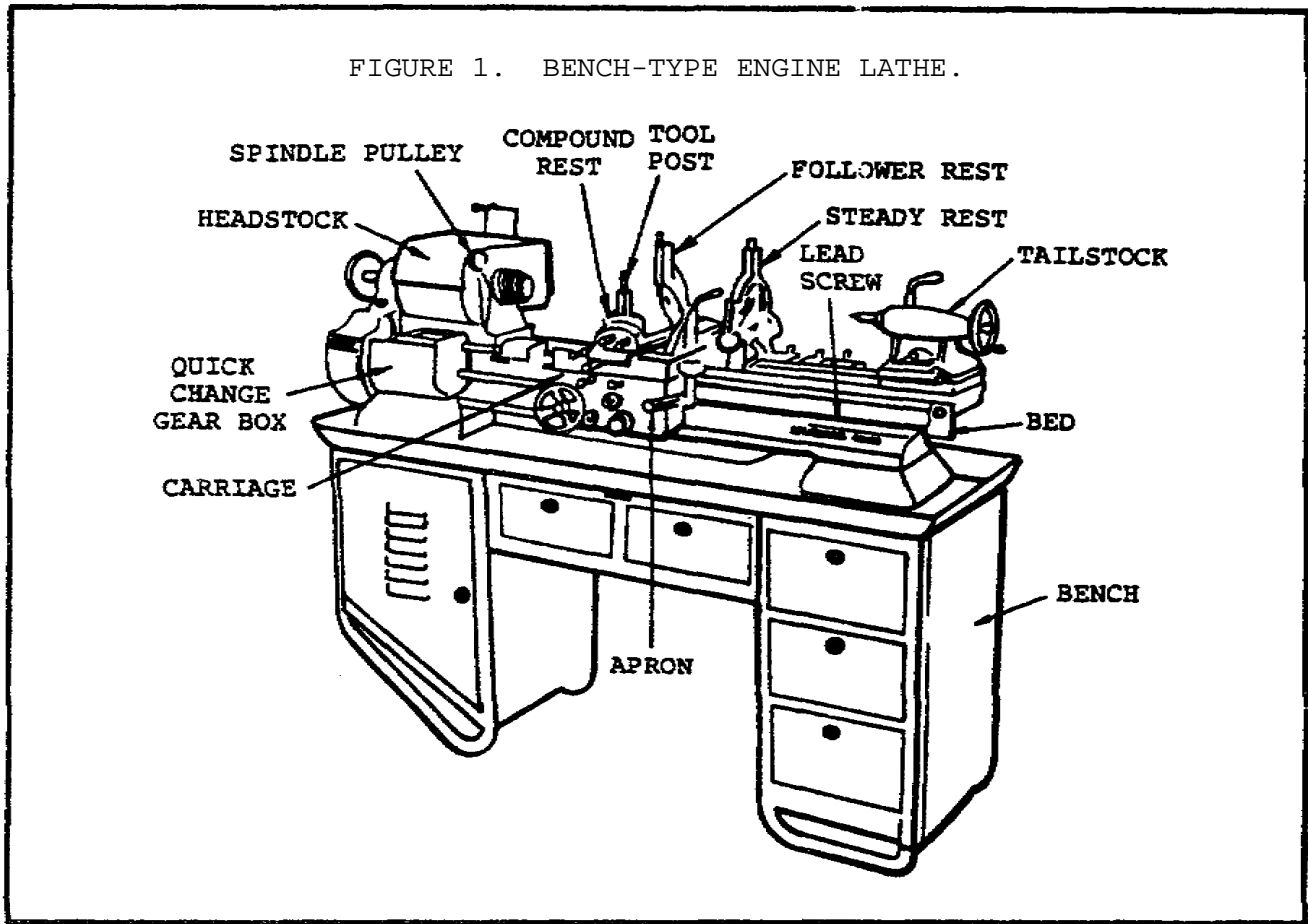
(1) *General.* The engine lathe is intended for general purpose lathe work and is the usual lathe found in the machine shop. The engine lathe may be bench or floor mounted; it may be referred to as a toolroom-type lathe, or a sliding-gap or extension-type lathe. The engine lathe consists mainly of a headstock, a tailstock, a carriage, and a bed upon which the tailstock and carriage move. Most engine lathes are back-gearred and high torque, which is required for machining large diameter workpieces and taking heavy cuts. The usual engine lathe has longitudinal power and crossfeeds for moving the carriage. It has a lead screw with gears to provide various controlled feeds for cutting

threads. Engine lathes are made in various sizes; the size is determined by the manufacturer. Generally, the size is determined by the following measurements: either (a) the diameter of the workpiece will swing over the bed, or (b) it will swing over the cross-slide, and (c) the length of the bed, or (d) the maximum distance between centers. For example, using method (a) and (c), a 14 inch x 6-foot lathe has a bed that is 6 feet long and will swing work (over the bed) up to 14 inches in diameter. The maximum distance between centers indicates the dimension, in inches, of the longest length of material that can be placed in the lathe.

(2) *Bench-Type Engine Lathe.*

(a) The bench-type engine lathe (figure 1 on the following page), is the most common general purpose screw cutting lathe normally found in a small shop. It commonly has an 8 to 12 inch swing and a 3 to 5 foot bed length, the size being limited by the practicality of bench mounting. The bench upon which the lathe is mounted may be a standard wood-topped shop bench or a special metal lathe bench with drawers for storing the lathe accessories.

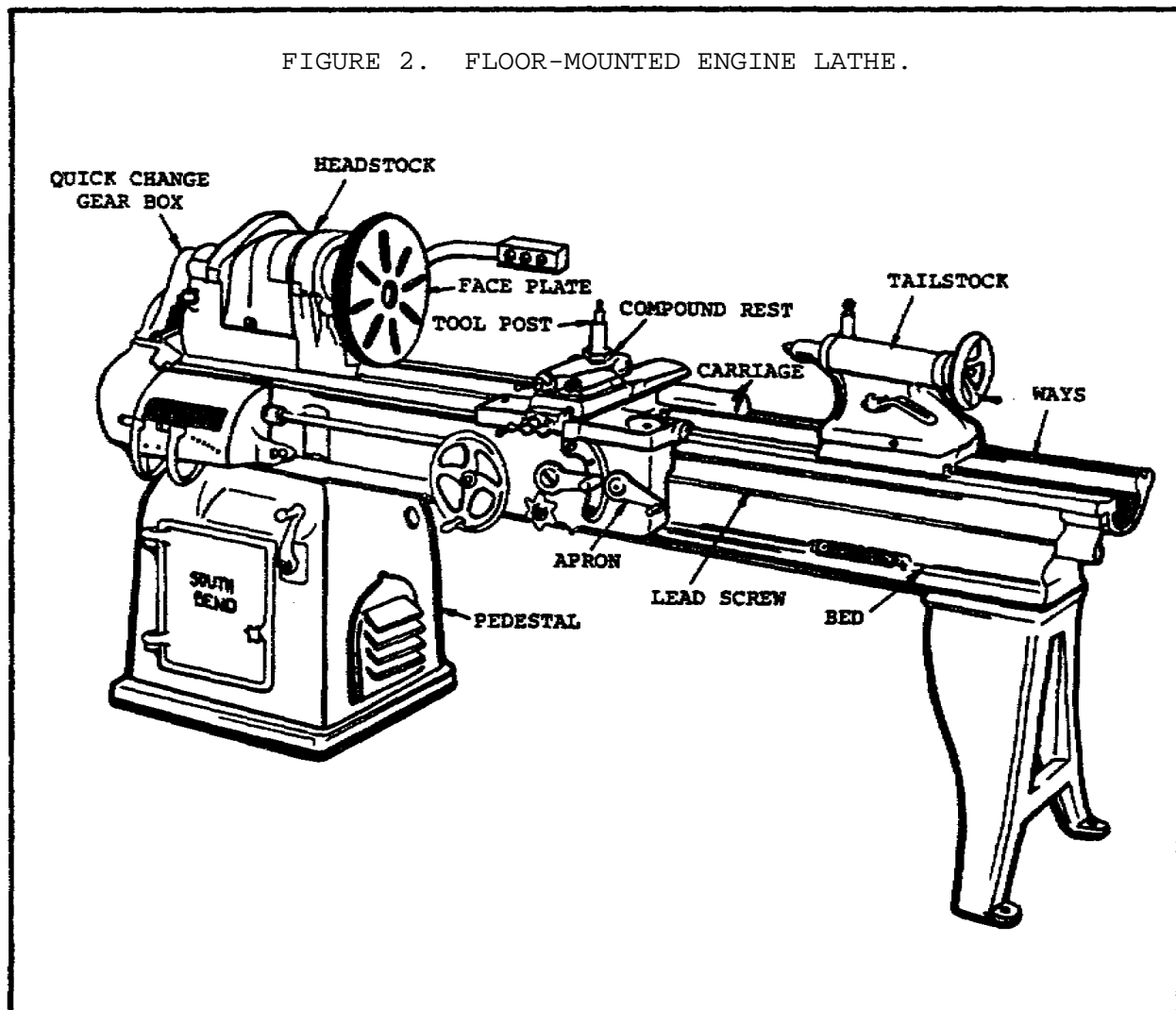
(b) The bench-type engine lathe is generally powered by an electric motor, mounted to the bench behind the lathe headstock, and is driven by means of a flat leather belt. Some bench lathes use an underneath motor drive where the drive belt passes through a hole in the bench. This arrangement is convenient where space in the shop is limited. The bench-type engine lathe is generally equipped with the necessary tools, chucks, lathe dogs, and centers for normal operation. The lathe may have a quick-change gearbox for rapid change of threading feeds, or gears may have to be installed singly or in combination to achieve the proper threading feeds. The bench lathe may or may not have a power-operated crossfeed drive.



(3) *Floor-Mounted Engine Lathe.* The floor-mounted engine lathe (figure 2 on the following page) or pedestal-type engine lathe, is inherently more rigid than the bench-type lathe and may have a swing as great as 16 or 20 inches and a bed length as great as 12 feet, with 105 inches between centers. The drive motor is located in the pedestal beneath the lathe headstock. A tension release mechanism for loosening the drive belt is usually provided so that the drive belt may be quickly changed to different pulley combinations for speed changes. The headstock spindle is back-gearred to provide slow spindle speeds, and a quick-change gearbox for controlling the lead screw is installed on all currently manufactured floor-mounted lathes. The floor-mounted engine lathe usually has a power-operated crossfeed mechanism.

(4) *Toolroom Lathe.* The toolroom lathe is an engine lathe equipped with more precision accessories and built to greater standards of accuracy than standard engine lathes. It may be either floor-mounted or a bench-mounted. The toolroom-type lathe is usually supplied with a very

precise lead screw for threading operations. It comes equipped with precision accessories such as a collet, chuck attachment, a taper attachment, and a micrometer stop. Therefore, work of a better class and of a more complete nature may be accomplished on a toolroom-type engine lathe.



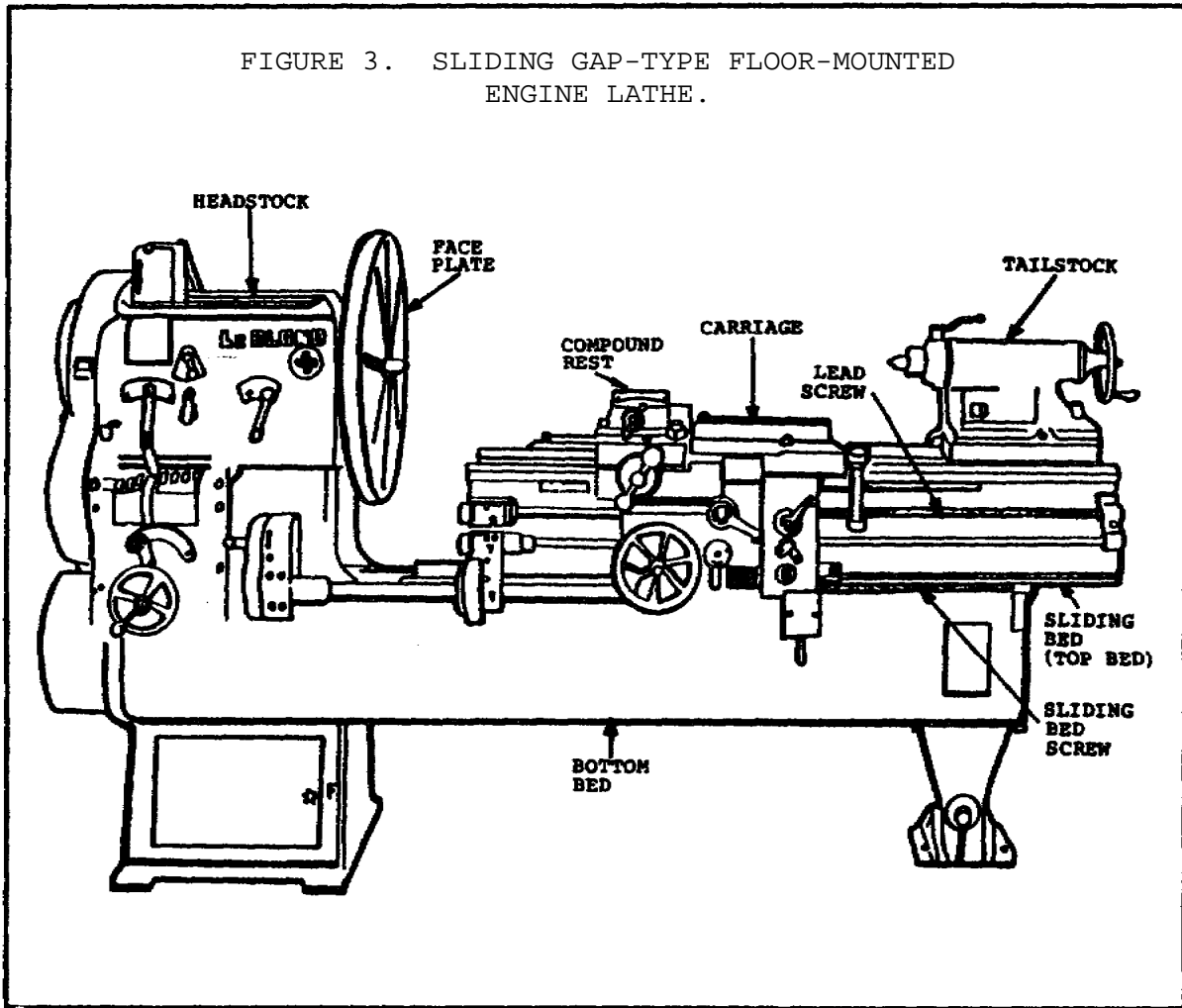
(5) *Sliding Gap-Type Floor-Mounted Engine Lathe.* The sliding gap-type floor-mounted lathe or extension gap lathe contains two lathe beds, the top bed or sliding bed, and the bottom bed (figure 3 on the following page). The sliding bed mounts the carriage and the tailstock and can be moved outward, away from the headstock as desired. By extending the sliding bed, material up to 28 inches in diameter may be swung on this lathe. The sliding bed may also be extended to accept between centers workpieces that would not normally fit in a standard lathe of the same size. Except for the

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 1

sliding gap feature, this lathe is similar to the floor-mounted engine lathe.

d. *Turret Lathes.*

(1) *General.* The turret lathe is a lathe used extensively for the high-speed production of duplicate parts. The turret lathe is so named because it has a hexagonal turret, or multiple tool holder, in place of the tailstock found on the engine lathe. Most turret lathes are equipped with a pump and basin for the automatic application of a coolant or cutting oil to the workpiece.



(2) *Floor-Mounted Horizontal Turret Lathe.* The floor-mounted horizontal turret lathe is intended for quick turning of bar stock and chucked workpieces with a minimum amount of adjustments between operations. The lathe uses a collet chuck

and a hollow headstock spindle for feeding bar stock into the machine, or may use a universal scroll chuck for swinging the workpiece. The size of the horizontal turret lathe is usually given as the diameter of bar stock that can be fed into the lathe through the headstock spindle. The size can also be classified by the swing. The turret of the turret lathe is usually power operated. It contains an indexing mechanism for bringing the tools (held on its six faces) against the workpiece in a preselected order. Separate feed stops are provided for each face of the turret. A quick hand-indexing four-sided turret is commonly mounted on the front of the cross-slide, and a holder for one or more tools often is mounted on the rear. The cross-slide may be either hand or power operated.

e. Special Purpose Lathes.

(1) *General.* Some lathes have characteristics that enable them to do certain work well. Some of these lathes are of the heavy-production type where large numbers of identical parts must be produced to make the operation more economical. Other special purpose lathes are specialized for machining specific items and cannot be adapted to the common types of lathe operations.

(2) *Bench-type Jeweler's Lathe.* The bench-type jeweler's lathe is actually a miniature engine lathe designed for the precision machining of small parts. The usual jeweler's lathe contains a collet-type chuck, lead screw, change gears for threading operations, and a precise manual crossfeed. Controls and feeds are calibrated in smaller increments than with the engine lathe and, as a result, workpieces of small dimensions can be machined to a great degree of accuracy. The jeweler's lathe is belt driven by an independent motor which can be mounted above or behind the lathe.

(3) *Other Special Purpose Lathes.* Other special purpose lathes include the production lathe, the automatic lathe, the automatic screw machine, the brakedrum lathe, the crankshaft lathe, the duplicating lathe, the multispindle lathe, and lathes designed for turning car axles or forming sheet metal.

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 1

f. *Essential Features of The Lathe.*

(1) *General.* To learn the operation of the lathe, one must first be familiar with the names and functions of the principal parts. In studying the principal parts in detail, remember that all lathes provide the same general function even though the design may differ among manufacturers. Figure 4 on the following page provides a general illustration of the parts normally found on a lathe. For specific details on a given lathe, refer to the manufacturer's technical manual for that machine.

(2) *Bed and Ways.* The bed is the base for the working parts of the lathe. The main feature of the bed is the ways which are formed on the bed's upper surface and which run the full length of the lathe. The tailstock and carriage slide on the ways in alignment with the headstock. The headstock is normally permanently bolted at one end (at the operator's left).

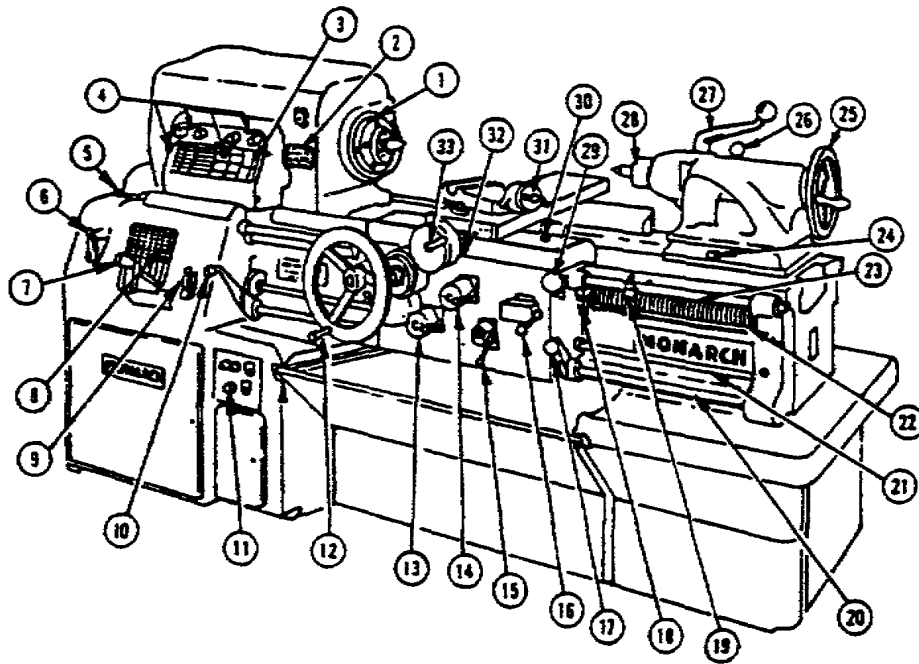
(a) The ways are accurately machined parallel to the axis of the spindle and to each other. The V-ways are guides that allow the carriage and the tailstock to move over them only in their longitudinal direction. The flat way takes most of the downward thrust. The carriage slides on the outboard V-ways which, because they are parallel to the V-ways, keep the carriage in alignment with the headstock and tailstock at all times. This is an absolute necessity if accurate lathe work is to be done. Some lathe beds have two V-ways and two flat ways, while others have four V-ways.

(b) For satisfactory performance of a lathe, the ways must be kept in good condition. A common fault of careless machinists is to use the bed as an anvil for driving arbors or as a shelf for hammers, wrenches, and chucks. Never allow anything to strike the ways or damage their finished surfaces in any way. Keep them free of chips. Wipe them off daily with an oiled cloth to help preserve their polished surface.

(3) *Headstock.*

(a) The headstock carries the head spindle and the mechanism for driving it. In the belt-driven type headstock, the driving mechanism consists merely of a cone pulley that drives the spindle

FIGURE 4. GEAR-HEAD ENGINE LATHE.

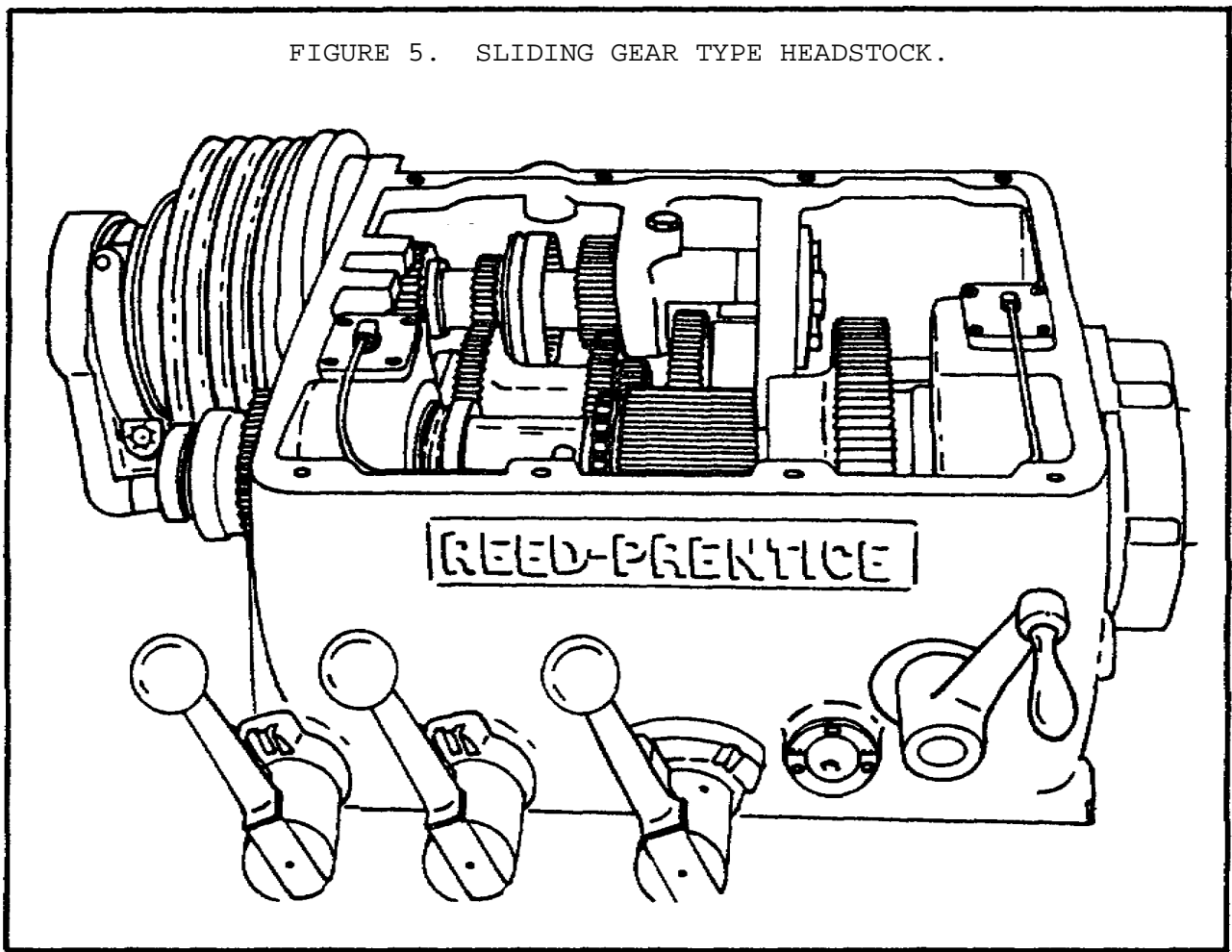


- | | |
|------------------------------------------|------------------------------------|
| 1. Headstock spindle | 17. Spindle control lever |
| 2. Identification plate | 18. Leadscrew reverse lever |
| 3. Spindle speed index plate | 19. Reverse rod stop dog |
| 4. Headstock spindle speed change levers | 20. Control rod |
| 5. Upper compound lever | 21. Feed rod |
| 6. Lower compound lever | 22. Lead screw |
| 7. Tumbler lever | 23. Reverse rod |
| 8. Feed-thread index plate | 24. Tailstock setover screw |
| 9. Feed-thread lever | 25. Tailstock handwheel |
| 10. Spindle control lever | 26. Tailstock clamping lever |
| 11. Electrical switch grouping | 27. Tailstock spindle binder lever |
| 12. Apron handwheel | 28. Tailstock spindle |
| 13. Longitudinal friction lever | 29. Chasing dial |
| 14. Cross-feed friction lever | 30. Carriage binder clamp |
| 15. Feed directional control lever | 31. Compound rest dial and handle |
| 16. Half nut closure lever | 32. Thread chasing stop |
| | 33. Cross-feed dial and handle |

directly or through the back gears. When the spindle is driven directly, it rotates the cone pulley. When the spindle is driven through the back gears, it rotates more slowly than the cone pulley, which in this case turns freely on the

spindle. Thus two speeds are available with each position of the belt on the cone; if the cone pulley has four steps, eight spindle speeds are available.

(b) The geared headstock shown in figure 5 is more complicated but more convenient to operate, because the speed is changed by changing or by shifting the gears. This headstock is similar to an automobile transmission except that it has more gear-shift combinations and, therefore, has a greater number of speed changes. A speed index plate, attached to the headstock, indicates the lever positions for the different spindle speeds. To avoid damage to the gear teeth, the lathe is always stopped before the gears are shifted.



(c) Figure 5 shows the interior of a typical geared headstock that has 16 different spindle speeds. The driving pulley at the left is driven at a constant speed by a motor located under the headstock. Various combinations of gears in the

headstock transmit power from the drive shaft to the spindle through an intermediate shaft. Use the speed-change levers to shift the sliding gears on the drive shaft and the intermediate shaft to line up the gears in different combinations. This produces the gear ratios needed to obtain the various spindle speeds. Note that the back gear lever has a high and low speed for each combination of the other gears.

(d) The headstock casing is filled with oil to lubricate the gears and the shifting mechanism contained within it. The parts not immersed in the oil are lubricated by either the splash produced by the revolving gears or by an oil pump. Be sure to keep the oil to the full level as indicated on the oil gage, and drain and replace the oil when it becomes dirty or gummy.

(e) The headstock spindle is the main rotating element of the lathe and is directly connected to the workpiece which revolves with it. The spindle is supported in bearings at each end of the headstock through which it projects. The section of the spindle between the bearings carries the pulleys or gears that turn the spindle. The nose of the spindle holds the driving plate, the faceplate, or a chuck. The spindle is hollow throughout its length so that bars or rods can be passed through it from the left and held in a chuck at the nose. The chuck end of the spindle is bored to a Morse taper to receive the solid center. The hollow spindle also permits the use of the draw-in collet chuck (to be discussed later in this lesson). At the other end of the spindle is the gear by which the spindle drives the feed and the screw-cutting mechanism through a gear train located on the left end of the lathe. A collar is used to adjust the end play of the spindle.

(f) The spindle is subjected to considerable torque because it drives the work against the resistance of the cutting tool, as well as driving the carriage that feeds the tool into the work. Because of the torque and pressure applied to the spindle, adequate lubrication and accurately adjusted bearings are absolutely necessary.

(4) *Tailstock.*

(a) The primary purpose of the tailstock is to hold the dead center to support one end of the work

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 1

being machined between centers. However, it can also be used to hold live centers, tapered shank drills, reamers, and drill chucks. The tailstock moves on the ways along the length of the bed to accommodate work of varying lengths. It can be clamped in the desired position by the tailstock clamping nut.

(b) The dead center is held in a tapered hole (bored to a Morse taper) in the tailstock spindle. The spindle is moved back and forth in the tailstock barrel for longitudinal adjustment. The handwheel is turned which turns the spindle-adjusting screw in a tapped hole in the spindle. The spindle is kept from revolving by a key that fits a spline, or keyway, cut along the bottom of the spindle.

(c) The tailstock body is made in two parts. The bottom, or base, is fitted to the ways; the top can move laterally on its base. The lateral movement can be closely adjusted by setscrews. Zero marks inscribed on the base and top indicate the center position and provide a way to measure setover for taper turning.

(d) Before inserting a dead center, a drill, or a reamer into the spindle, carefully clean the tapered shank and wipe out the tapered hole of the spindle. After a drill or reamer is placed into the tapered hole of the spindle, make sure that the tool will not turn or revolve. If the tool is allowed to revolve, it will score the tapered hole and destroy its accuracy. The spindle of the tailstock is engraved with graduations which help in determining the depth of a cut when a piece is drilled or reamed.

(5) *Carriage.*

(a) The carriage carries the crossfeed slide and the compound rest which in turn carries the cutting tool in the toolpost. The carriage slides on the ways along the bed (figure 6 on page 14).

(b) Figure 6, view B, shows a top view of the carriage. The wings of the H-shaped saddle contain the bearing surfaces which are fitted to the V-ways of the bed. The cross piece is machined to form a dovetail for the crossfeed slide. The crossfeed slide is closely fitted to the dovetail and has a tapered gib which fits between the carriage

dovetail and the matching dovetail of the crossfeed slide. The gib permits small adjustments to remove any looseness between the two parts. The slide is securely bolted to the crossfeed nut which moves back and forth when the crossfeed screw is turned by the handle. The micrometer dial on the crossfeed handle is graduated to permit accurate feed. Depending on the manufacturer of the lathe, the dial may be graduated so that each division represents a 1 to 1 ratio. The compound rest is mounted on top of the crossfeed slide.

(c) The carriage has T-slots or tapped holes for clamping work for boring or milling operations. When the lathe is used in this manner, the carriage movement feeds the work to the cutting tool which is revolved by the headstock spindle.

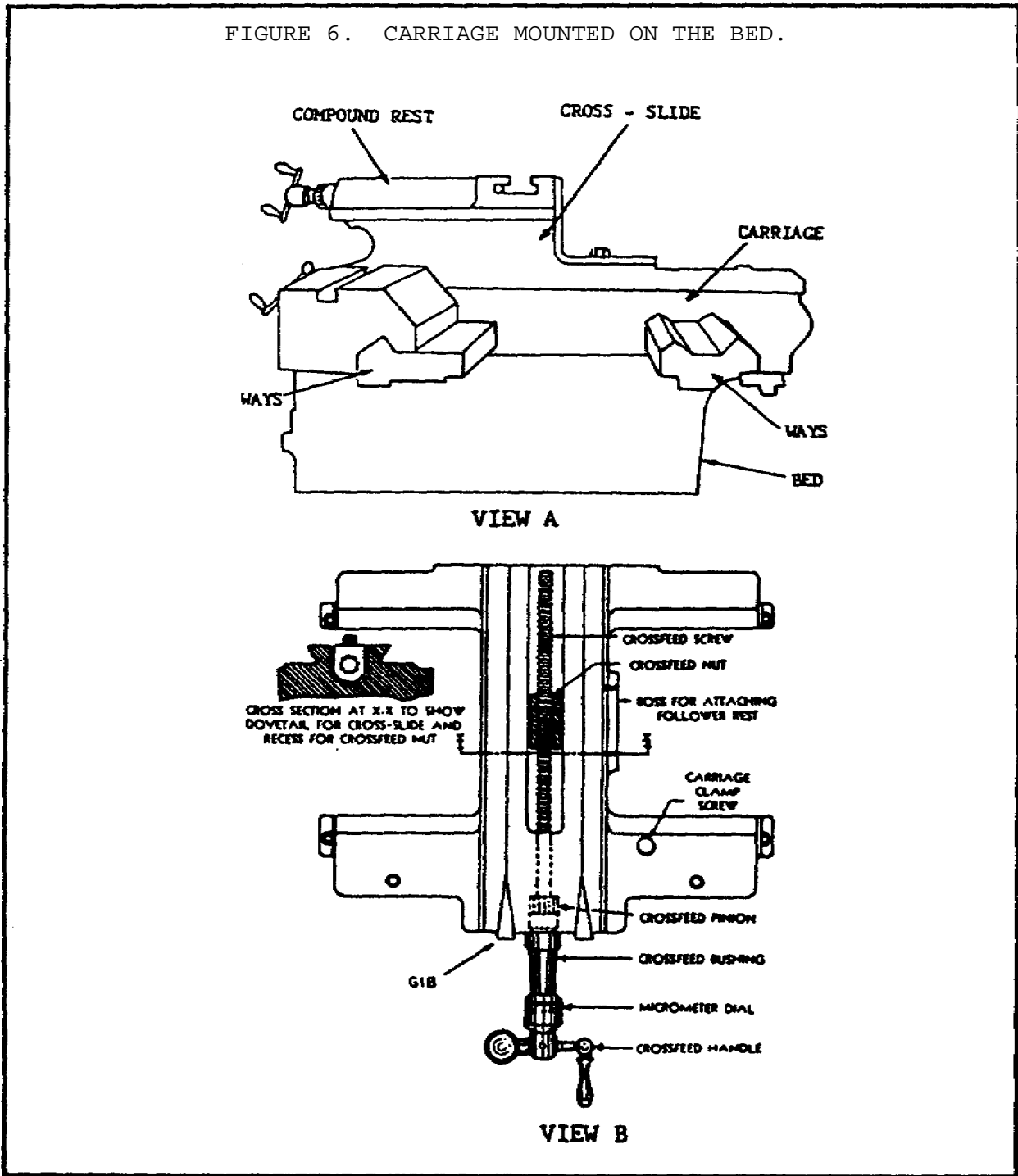
(d) The carriage can be locked in any position on the bed by tightening the carriage clamp screw. The clamp screw is to be used only when doing work for which longitudinal feed is not required, such as facing or cutting-off stock. Normally, the carriage clamp is kept in the released position. The carriage is always moved by hand to make sure that it is free before the automatic feed is applied.

(6) Apron. The apron (figure 2 on page 5) is attached to the front of the carriage. It contains the mechanism that controls the movement of the carriage for longitudinal feed and thread cutting. It controls the lateral movement of the cross-slide. One should thoroughly understand the construction and operation of the apron before attempting to operate the lathe. In general, a lathe apron contains the following mechanical parts:

(a) A longitudinal feed handwheel for moving the carriage by hand along the bed. This handwheel turns a pinion that meshes with a rack gear that is secured to the lathe bed.

(b) Gear trains driven by the feed rod. These gear trains transmit power from the feed rod to move the carriage along the ways and to move the cross-slide across the ways, thus providing powered longitudinal feed and crossfeed.

FIGURE 6. CARRIAGE MOUNTED ON THE BED.



(c) Friction clutches operated by knobs on the apron are used to engage or disengage the power-feed mechanism. (Some lathes have a separate clutch for longitudinal feed and crossfeed; others have a single clutch for both.)

NOTE

The power feeds are usually driven through a friction clutch to prevent damage to the gears if excessive strain is put on the feed mechanism. If clutches are not provided, there is some form of safety device that operates to disconnect the feed rod from its driving mechanism.

(d) A selective feed lever or knob is provided for engaging the longitudinal feed or crossfeed as desired.

(e) Half-nuts are used to engage and disengage the lead screw when the lathe is used to cut threads. They are opened or closed by a lever that is located on the right side of the apron. The half-nuts fit the thread of the lead screw which turns then like a bolt in a nut when they are clamped over it. The carriage is then moved by the thread of the lead screw instead of by the gears of the apron feed mechanisms. (The half-nuts are engaged only when the lathe is used to cut threads, at which time the feed mechanism must be disengaged. An interlocking device, that prevents the half-nuts and the feed mechanism from engaging at the same time, is usually provided as a safety feature.)

(f) The manufacturers of lathe aprons differ somewhat in their construction and in the location of the controlling levers and knobs. However, they are all designed to perform the same function. The principal difference is in the gear trains for driving the automatic feeds. For example, in some aprons there are two separate gear trains with separate operating levers for longitudinal feed and crossfeed. In others, both feeds are driven from the same driving gear on the feed rod through a common clutch; they have a selective lever for connecting the drive to either the longitudinal feed or the crossfeed.

(7) *Feed Rod.*

(a) The feed rod transmits power to the apron to drive the longitudinal feed and crossfeed mechanisms. The feed rod is driven by the spindle through a train of gears, and the ratio of its speed to that of the spindle can be varied by

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 1

changing gears to produce various rates of feed. The rotating feed rod drives the gears in the apron. These gears in turn drive the longitudinal feed and crossfeed mechanisms through friction clutches, as previously explained in (6)(c) on page 14.

(b) Lathes which do not have a separate feed rod have a spline in the lead screw to serve the same purpose. The apron belongs to a lathe of this type and is driven by the spline in the lead screw. If a separate feed rod was used, it would drive the feed worm in the same manner. The spline permits the worm, which is keyed to it, to slide freely along its length to conform with the movement of the carriage apron.

(8) *Lead Screw.*

(a) The lead screw is used for thread cutting. Along its length are accurately cut Acme threads which engage the threads of the half-nuts in the apron when the half-nuts are clamped over it. When the lead screw turns inside the closed half-nuts, the carriage moves along the ways a distance equal to the lead of the thread in each revolution of the lead screw. Since the lead screw is connected to the spindle through a gear train (to be discussed in paragraph (9)(a) below), the lead screw rotates with the spindle. Whenever the half-nuts are engaged, the longitudinal movement of the carriage is directly controlled by the spindle rotation. The cutting tool is moved a definite distance along the work for each revolution of the spindle.

(b) The ratio of the threads per inch of the thread being cut and the thread of the lead screw is the same as the ratio of the speeds of the spindle and the lead screw. For example: If the lead screw and spindle turn at the same speed, the number of threads per inch being cut is the same as the number of threads per inch of the lead screw. If the spindle turns twice as fast as the lead screw, the number of threads being cut is twice the number of threads per inch of the lead screw.

(c) Any number of threads can be cut by merely changing the gears in the connecting gear train to obtain the desired ratio of the spindle and the lead screw speeds.

(9) *Quick-Change Gear Mechanism.*

(a) To do away with the inconvenience and loss of time involved in removing and replacing change gears, most modern lathes have a self-contained change gear mechanism, commonly called a "quick-change gear box." There are a number of types used on different types of lathes, but they are all similar in principle.

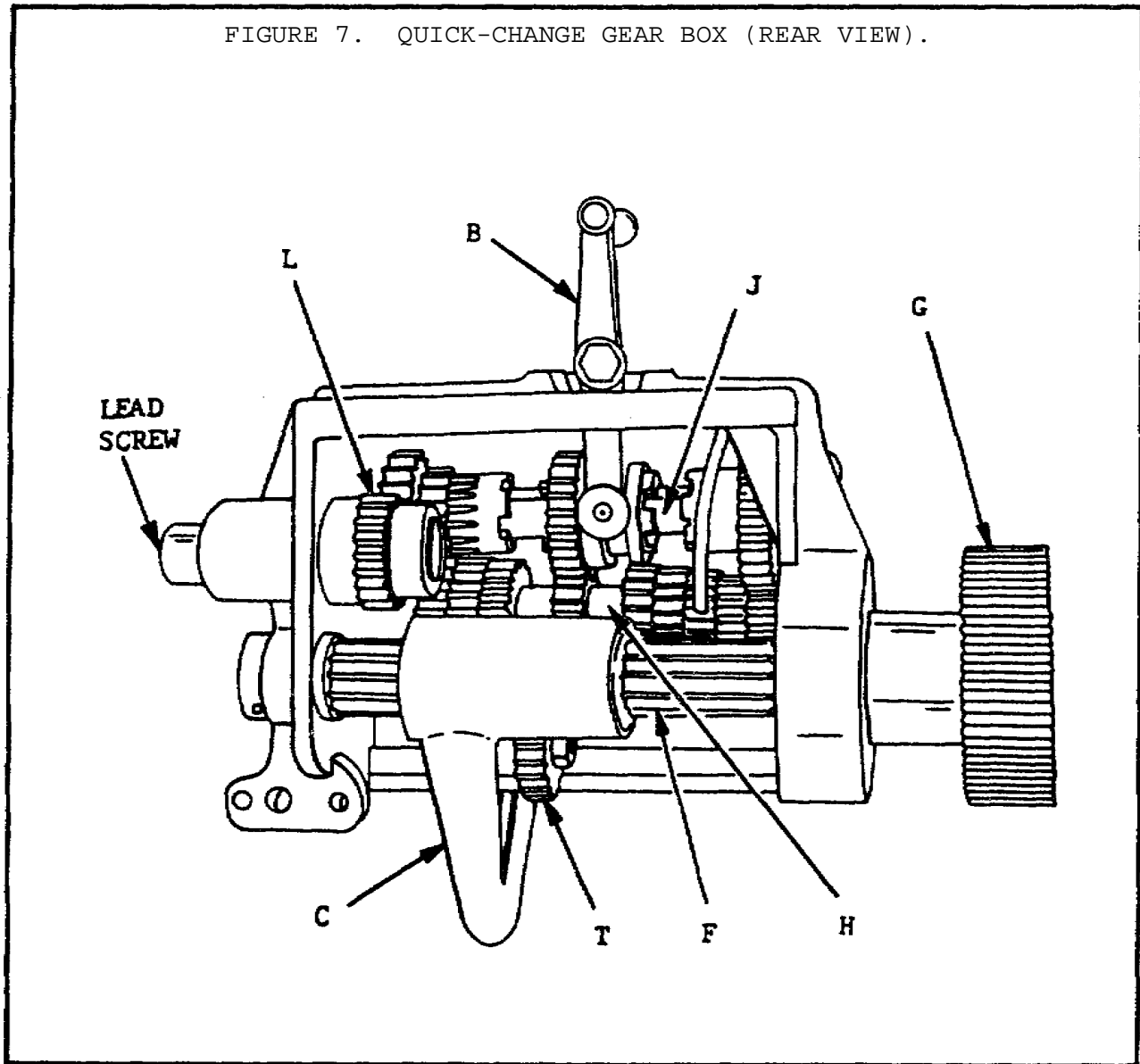
(b) The quick-change gear box mechanism consists of a cone-shaped group of change gears. One can instantly connect any single gear in the gear train by a sliding tumbler gear controlled by a lever. The cone of gears is keyed to a shaft which drives the lead screw (or feed rod) directly or through an intermediate shaft. Each gear in the cluster has a different number of teeth and hence produces a different ratio when connected in the train. Sliding gears also produce other changes in the gear train to increase the number of different ratios one can get with the cone of change gears. All changes are made by shifting the appropriate levers or knobs. An index plate or chart mounted on the gear box indicates the position in which to place the levers to obtain the necessary gear ratio to cut the threads or produce the feed desired (see figure 7 on the following page).

(c) Figure 7 depicts the rear view of one type of gear box. The splined shaft turns with gear G, which is driven by the spindle through the main gear train mounted on the end of the lathe. Shaft F in turn drives shaft H through the tumbler gear T, which can be engaged with any one of the cluster of eight different size gears on shaft H by means of the lever C. Shaft H drives shaft J through a double-clutch gear, which takes the drive through one of three gears, depending on the position of lever B (right, center or left). Shaft J drives the lead screw through gear L.

(d) Either the lead screw or the feed rod can be connected to the final driveshaft of the gear box by engaging the appropriate gears. The lathe gear box shown in figure 7 has no feed rod.

(e) Twenty-four different gear ratios are provided by the quick-change gear box. The lower lever has eight positions, each of which places a different gear in the gear train and hence produces eight different gear ratios. The three positions

FIGURE 7. QUICK-CHANGE GEAR BOX (REAR VIEW).



of the upper level produce three different gear ratios for each of the 8 changes obtained with the lower lever, thus making 24 combinations in the box alone. This range can be doubled by using the sliding compound gear which provides a high- and low-gear ratio in the main gear train. This gives two ratios for every combination obtainable in the box, 48 combinations in all.

(10) *Compound Rest*. The compound rest (figure 8 on page 20) provides a rigid adjustable mounting for the cutting tool. The compound rest assembly has the following principal parts:

(a) The compound rest swivel (2) can be swung around to any desired angle and clamped in position. It is graduated over an arc of 90° on each side of its center position for ease in setting it to the desired angle. This feature is used in machining short, steep tapers such as the angle on beveled gears, valve disks, and lathe centers.

(b) The compound rest top or top slide (3), is mounted on the swivel section (2) on a dovetailed side. It is moved along the slide by the compound rest feed screw turning in the nut (4), operated by the handle (5), in a manner similar to the crossfeed described in paragraph (5)(b) beginning on page 12. This provides for feeding at any angle (determined by the angular setting of the swivel section), while the cross-slide feed provides only for feeding at right angles to the axis of the lathe. The graduated collar on the compound rest feed screw reads in thousandths of an inch for fine adjustment in regulating the depth of cut.

(11) *Toolposts.*

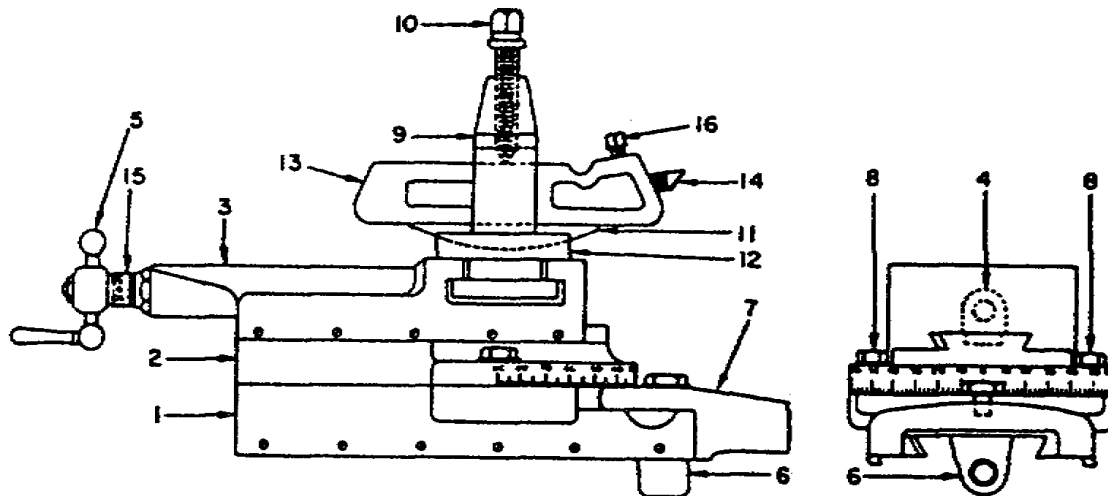
(a) Three popular types of toolposts are the standard, castle, and the quick change. The sole purpose of the toolpost is to provide a rigid support for the toolholder.

(b) The standard toolpost is mounted in the T-slot of the compound rest top as shown in figure 8. A forged tool or a toolholder (13) is inserted in the toolpost and rests on the toolpost wedge (11) and the toolpost ring (12). By tightening the setscrew, with the tool placed in the desired position, the whole unit can be clamped in place.

(12) *Cutting Toolholders.*

(a) *General.* Common cutter bits are generally made from standard sizes of bar stock to fit into a forged cutting toolholder at an approximate 15° positive rake angle. The toolholder is fastened to the toolpost of the lathe. Special tools such as the knurling tool and the thread cutting toolholder are furnished with their own special forged toolholder and, therefore, may be fastened directly to the toolpost of the lathe. Carbide-tipped cutter bits are generally unsuitable for mounting in forged toolholders. They are fastened directly

FIGURE 8. COMPOUND REST.



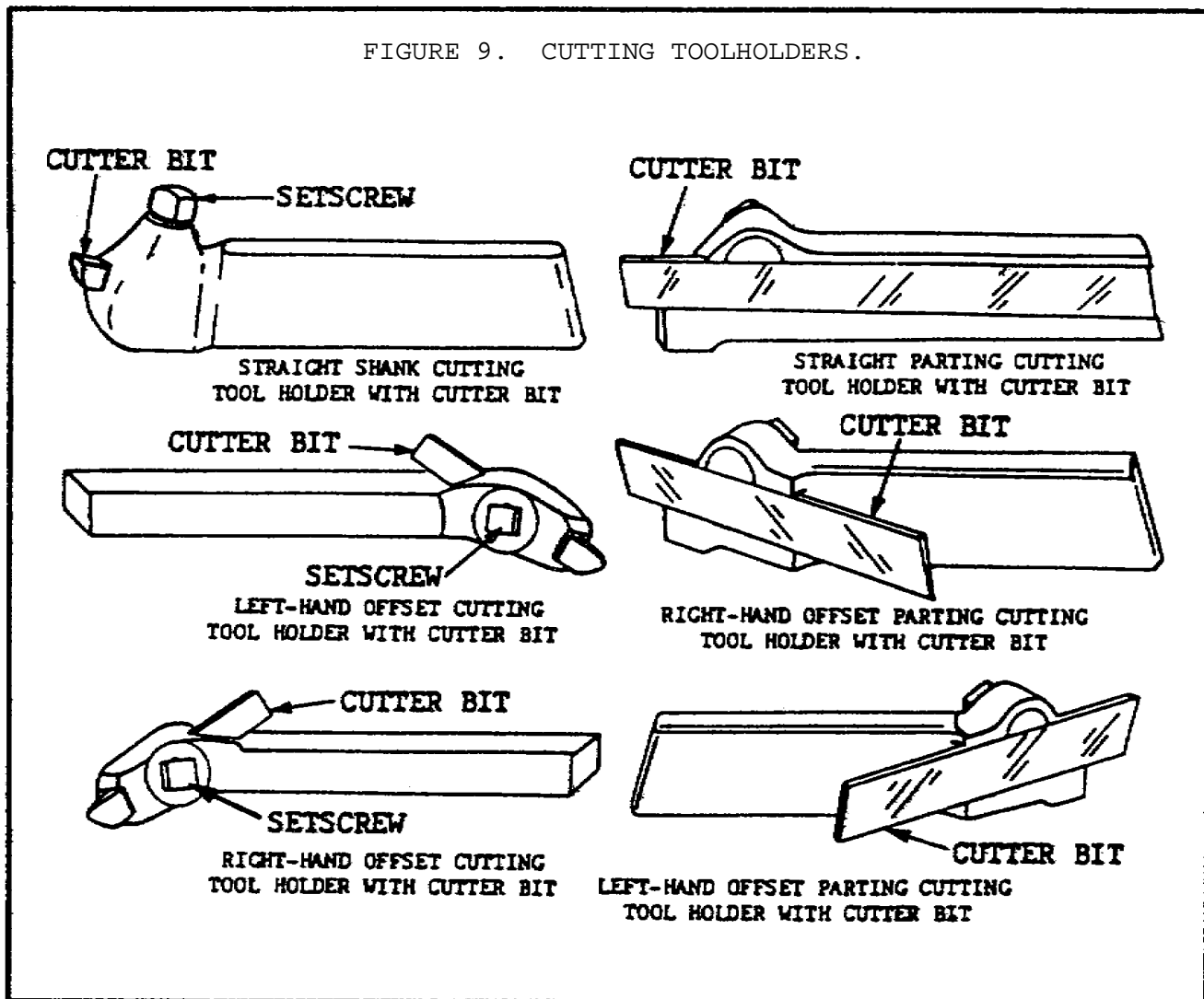
- | | | |
|-------------------------------------|---------------------------|------------------------|
| 1. Cross-slide. | 6. Crossfeed nut. | 11. Toolpost wedge. |
| 2. Compound rest swivel. | 7. Chip guard. | 12. Toolpost ring. |
| 3. Compound rest top. | 8. Swivel securing bolts. | 13. Toolholder. |
| 4. Compound rest nut. | 9. Toolpost. | 14. Cutting tool. |
| 5. Compound rest feed screw handle. | 10. Toolpost setscrew. | 15. Micrometer collar. |

to the lathe toolpost or mounted in an open side toolpost to provide rigid support for the bit.

(b) *Straight-Shank Cutting Toolholder.* The straight-shank cutting toolholder (figure 9 on the following page) may be used to support round-nose turning cutter bits, right-hand and left-hand turning cutter bits, and thread cutter bits. The holder is made of forged steel and contains a hardened steel setscrew for locking the cutter bit in place.

(c) *Right-Hand and Left-Hand Offset Cutting Toolholder.* The right-hand and left-hand offset cutting toolholders (figure 9) are designed to support right-hand and left-hand facing cutter bits which require that the bit be supported at an angle to the workpiece axis. The holder has a setscrew for locking the cutter bit in place.

FIGURE 9. CUTTING TOOLHOLDERS.



(d) *Straight Parting Cutting Toolholder.* The straight parting cutting toolholder (figure 9) is a forged steel holder shaped to hold flat, thin-sectioned parting tools which are used to cut and separate pieces of stock on the lathe.

(e) *Right-Hand and Left-Hand Offset Parting Cutting Toolholder.* The right-hand and left-hand offset parting cutting toolholders (figure 9) are similar to the straight parting cutting toolholder but are designed to hold the parting cutter bit at an angle to the holder shank. The offset toolholder is generally used when the workpiece is to be parted, because the stationary parts of the lathe may interfere with the holder if the straight parting-cutting toolholder is used. In either case, the compound rest of the lathe must be adjusted so that the parting cutter bit enters the workpiece at the correct angle (perpendicular to the workpiece).

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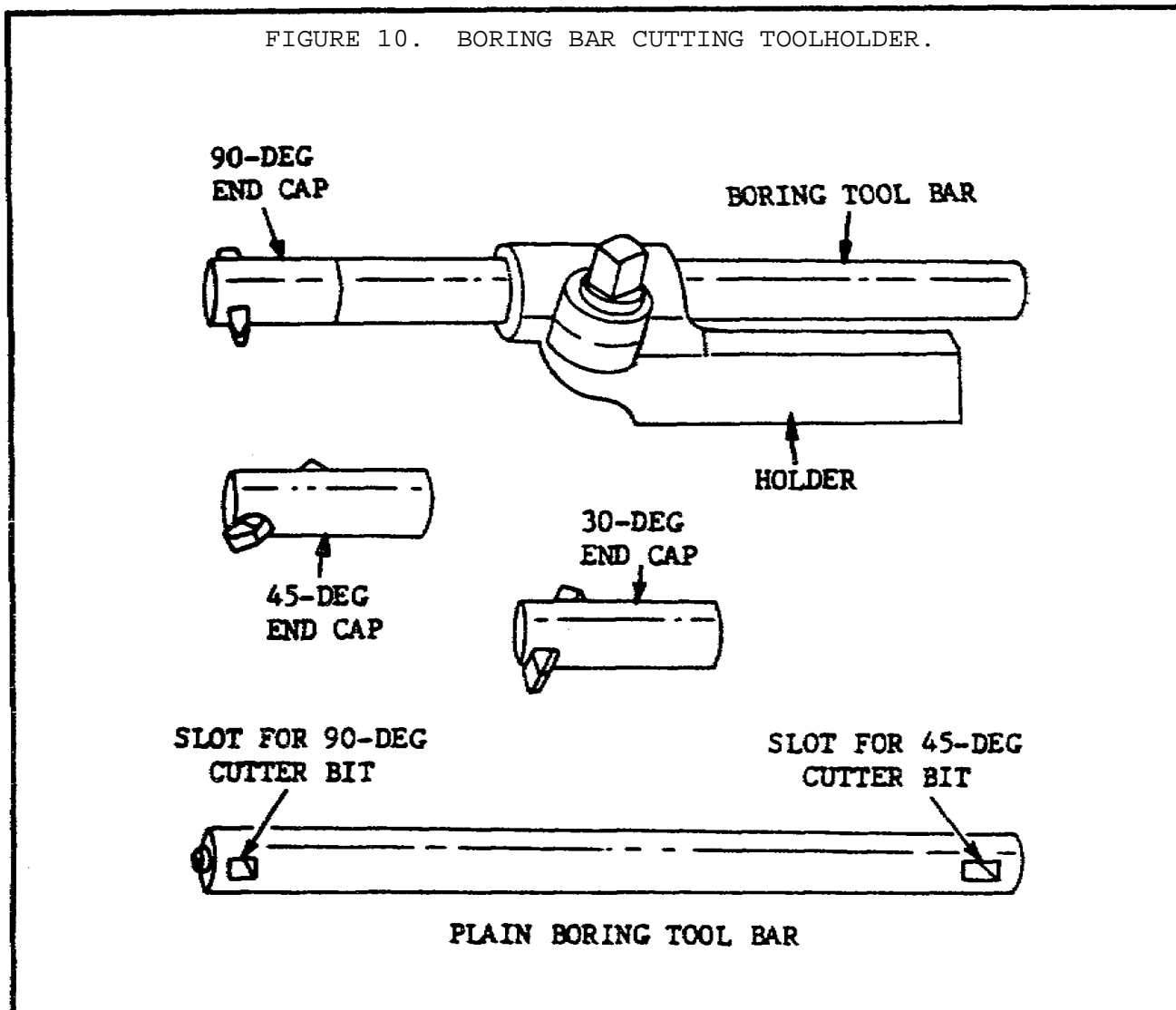
(f) *Boring Bar Cutting Toolholder.* A lathe boring bar cutting toolholder comes in several commercial types (figure 10 on the following page). It consists of three parts: the holder, the interchangeable end cap, and the boring tool bar. The boring tool bar is a rod with one end threaded to accept an end cap. Three end caps are supplied; each end cap is slotted at different angles to accept a cutter bit. The standard angles are 30°, 45°, and 90°. Plain boring toolholders without caps are often made to accept cutter bits at each end, one having a 90° slot, and the other having a 45° slot. The holder is made of forged steel. It has a shank similar to that of the other cutting toolholders. The holder is secured to the toolpost by the lathe toolpost screw. The boring bar is adjustable in the holder and can be locked in any desired position.

3. Lathe Cutting Tools

a. *General.* A machine tool is no more efficient than its cutting tool. There is nothing in shop work that should be given more thoughtful consideration than cutting tools. Time is always wasted if an improperly shaped tool is used. The cutting action of the tool depends on its shape and its adjustment in the holding device. Lathe cutter bits may be considered as wedges which are forced into the material to cause compression, with a resulting rupture or plastic flow of the material. The rupture or plastic flow is called cutting. To machine metal efficiently and accurately, it is necessary that the cutter bits have keen, well-supported cutting edges, and that they be ground for the particular metal being machined and the type of cut desired. Cutter bits are made from several types of steel, the most common of which are described in the following subparagraphs.

(1) *Carbon Steel.* Carbon steel, or tool steel is high in carbon content, hardens to a high degree of hardness when properly heated and quenched. The carbon-steel tool will give good results as long as constant care is taken to avoid overheating or "bluing," since the steel will lose its temper or hardness at a relatively low heat becoming ineffective as a cutting tool. For low-speed turning, high carbon steels give satisfactory results and are more economical than other materials.

FIGURE 10. BORING BAR CUTTING TOOLHOLDER.



(2) *High-Speed Steel*. High-speed steel is alloyed with tungsten and sometimes with chromium, vanadium, or molybdenum. Although not as hard as properly tempered carbon steel, the majority of lathe cutting tools are made of high-speed steel because it retains its hardness at extremely high temperatures. Cutter bits made of this material can be used without damage at speeds and feeds which heat the cutting edges to a dull red.

(3) *Stellite*. These cutter bits will withstand higher cutting speeds than high-speed steel cutter bits. Stellite is a nonmagnetic alloy which is harder than common high-speed steel. The tool will not lose its temper, even though heated red hot from the friction that is generated by taking a cut. Stellite is more brittle than high-speed steel. To prevent breaking or chipping, it requires just enough clearance to permit the tool

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to cut freely. Stellite is also used for machining hardened steel, cast iron, bronze, etc.

(4) *Tungsten Carbide.* Tungsten carbide is used to tip cutter bits when maximum speed and efficiency is required for materials which are difficult to machine. Although expensive, these cutter bits are highly efficient for machining cast iron, alloyed cast iron, copper, brass, bronze, aluminum, Babbitt metal, and such abrasive nonmetallic materials as fiber, hard rubber, and bakelite. Cutter bits of this type require very rigid support and are usually held in open-side toolposts. They require special grinding wheels for sharpening, since tungsten carbide is too hard to be redressed on ordinary grinding abrasive wheels.

(5) *Tantalum Carbide and Titanium Carbide.* These cutting tools are similar to tungsten carbide tools but are used mostly for machining steel where extreme heavy cuts are taken and heat and pressure tend to deform the cutting edge of the other types of cutting tools.

b. *Terms And Definitions Applied To Single-Pointed Cutter Bits.* The terms and definitions in subparagraphs (1) through (7) below are applied to tools used for turning, planing, boring, etc., which have a cutting edge at one end (figure 11 on the following page). This cutting edge may be formed on one end of a solid piece of steel, or the cutting part of the tool may consist of an insert or tip which is held to the body of the tool either by brazing, welding, or by mechanical means.

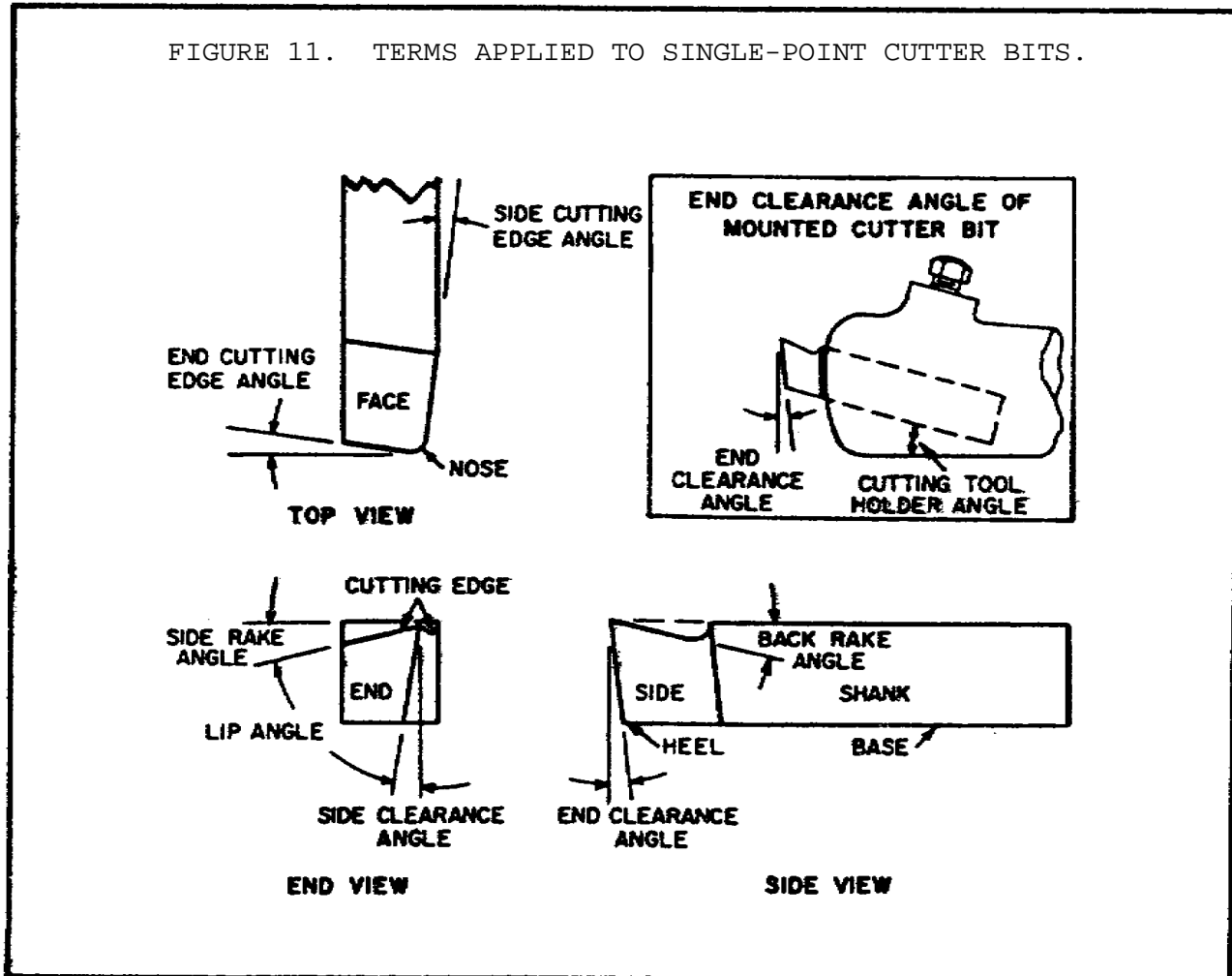
(1) *Shank.* The shank is the main body of the tool.

(2) *Nose.* The nose is the part of the cutter bit which is shaped to produce the cutting edges.

(3) *Face.* The face of the cutter bit is the surface at the upper side of the cutting edge on which the chip strikes as it is separated from the workpiece.

(4) *Side.* The side of the cutter bit is the near-vertical surface which, with the end of the bit, forms the profile of the bit. The side is the leading surface of the cutter bit used when cutting stock.

FIGURE 11. TERMS APPLIED TO SINGLE-POINT CUTTER BITS.



(5) *Base*. The base is the bottom surface of the shank of the cutter bit.

(6) *End*. The end of the cutter bit is the near-vertical surface which, with the side of the bit, forms the profile of the bit. The end is the trailing surface of the cutter bit when cutting.

(7) *Heel*. The heel is the portion of the cutter bit base immediately below and supporting the face.

c. *Angles of Cutter Bits*. The successful operation of the lathe and the quality of work that may be achieved depend largely on the angles that form the cutting edge of the cutter bit (figure 11). The profiles of the bit may be of any shape so long as the cutting edge is properly shaped. The five angles are used to define the cutting edge, to prevent supporting surfaces of the bit from rubbing against the workpiece, and to establish a path for the chips being removed.

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Improperly ground angles will result in weakening and breaking the cutting edge and overheating the bit.

d. *Recommended Clearance and Rake Angles.* Table 1 on the following page lists the clearance and rake angles for various materials that are to be machined. When grinding cutter bits, the lip angle should be considered in selecting the proper angles from the table.

e. *Common Types Of Cutter Bits.*

(1) *General.* Cutter bits (figure 12 on page 28) are made from standard sizes of bar stock to fit into cutting toolholders which in turn are fastened to the toolpost of the lathe. If the cutter bit is to be used for heavy roughing, where a finished surface is not expected, the nose should be ground with a very small radius (approximately 1/64 inch). If the cutter bit is to be used for general shaping and finishing, the nose should be more rounded (approximately 1/32-to 1/16 inch radius). The following cutter bits are identified by their function.

(2) *Right-Hand Turning Cutter Bit.* The right-hand turning cutter bit is shaped to be fed from right to left. The cutting edge is on the left side of the bit and the face slopes down away from the cutting edge. The left side and the end of the tool are ground with sufficient clearance to permit the cutting edge to bear upon the workpiece without the heel of the bit rubbing against the workpiece. The right-hand turning cutter bit is ideal for taking light roughing cuts as well as general all-around machine work.

(3) *Left-Hand Turning Cutter Bit.* The left-hand turning cutter bit (figure 12) is just the opposite of the right-hand turning cutter bit, being designed to cut the metal when fed from left to right. It is used for all around machine work when right-to-left turning is impractical.

(4) *Round-Nose Turning Cutter Bit.* The round-nose turning cutter bit (figure 12) is used for all around machine work and may be used for taking light roughing or finishing cuts. Usually the face is ground with a right sloping side rake so that

TABLE 1. CLEARANCE AND RAKE ANGLES FOR LATHE CUTTER BITS.

Material	Side clearance angle (deg.)	End clearance angle (deg.)	Back rake angle (deg.)	Side rake angle (deg.)
Aluminum.....	5-10	5-9	10-30	16-20
Brass.....	5-10	5-8	0-8	0-8
Bronze, free cutting.....	5-10	5-9	0-8	2-8
Bronze, tough.....	10-15	8-12	6-15	7-25
Cast iron.....	5-10	5-9	5-8	12-14
Copper.....	7-14	7-12	8-16	16-25
Magnesium alloy.....	6-10	6-10	5-9	3-5
Monel.....	6-15	6-13	4-10	10-14
Plastic, cast.....	12	10	30	25
Plastic, cold molded.....	10	10	0	0
Plastic, hot molded.....	6	6	10	20
Plastic, laminated.....	8	8	30	30
Steel, hard.....	5-10	5-9	6-14	10-14
Steel, soft.....	5-12	5-9	8-17	14-20
Steel, stainless.....	5-12	5-10	8-17	0-10
Steel, very hard.....	5-10	5-9	4-10	6-12
Wood.....	20	20	30	30

the bit may be fed from right to left, although it is often ground without any side rake so that the feed may be in either direction.

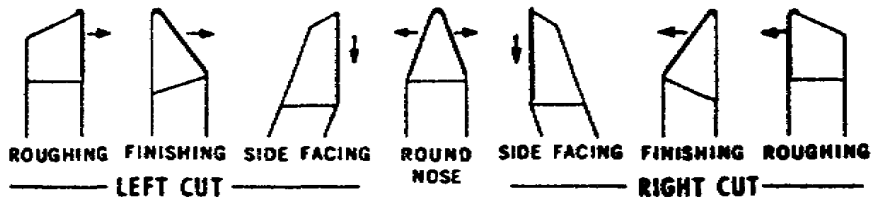
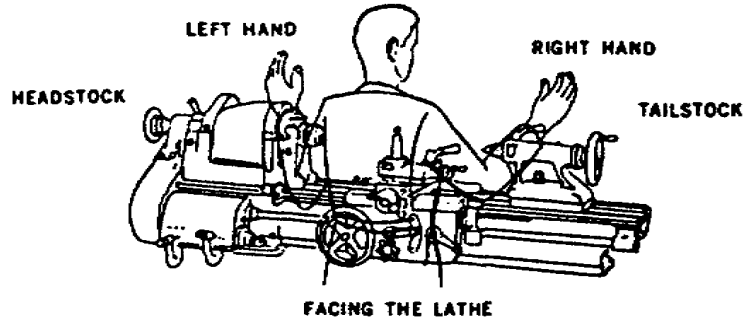
(5) *Right-Hand Facing Cutter Bit.* The right-hand facing cutter bit is intended for facing on right-hand shoulders and the right end of the workpiece. The cutting edge is on the left-hand side of the bit, and the nose is sharp to permit machining a square corner. The direction of feed for the facing bit should be away from the axis of the workpiece.

(6) *Left-Hand Facing Cutter Bit.* The left-hand facing cutter bit is just the opposite of the right-hand facing cutter bit; it is intended for facing the left side of the shoulders.

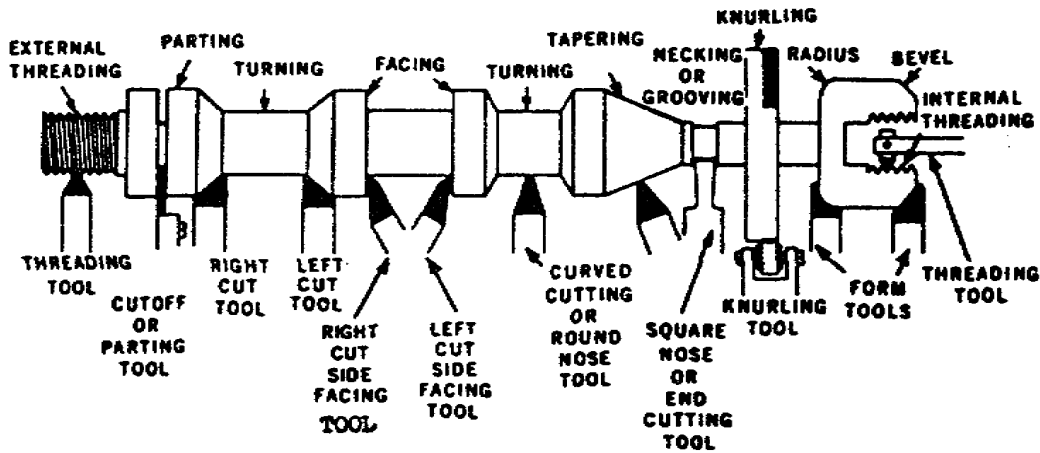
(7) *Parting Cutter Bit.* The parting cutter bit has its principal cutting edge at the end. Both sides must have sufficient clearance to prevent

FIGURE 12. COMMON TYPES OF CUTTER BITS.

THIS WILL HELP YOU TO IDENTIFY A RIGHT-CUT AND A LEFT-CUT TOOL.



COMMON CUTS MADE BY DIFFERENT CUTTING TOOLS.



binding and should be ground slightly narrower at the back than at the cutting edge. The bit is convenient for machining necks and grooves, square corners, etc., as well as for cutting-off operations.

(8) Thread Cutter Bit. The thread cutter bit has its cutting edge ground to a 60° angle. This form will cut sharp V-threads. Usually the face of

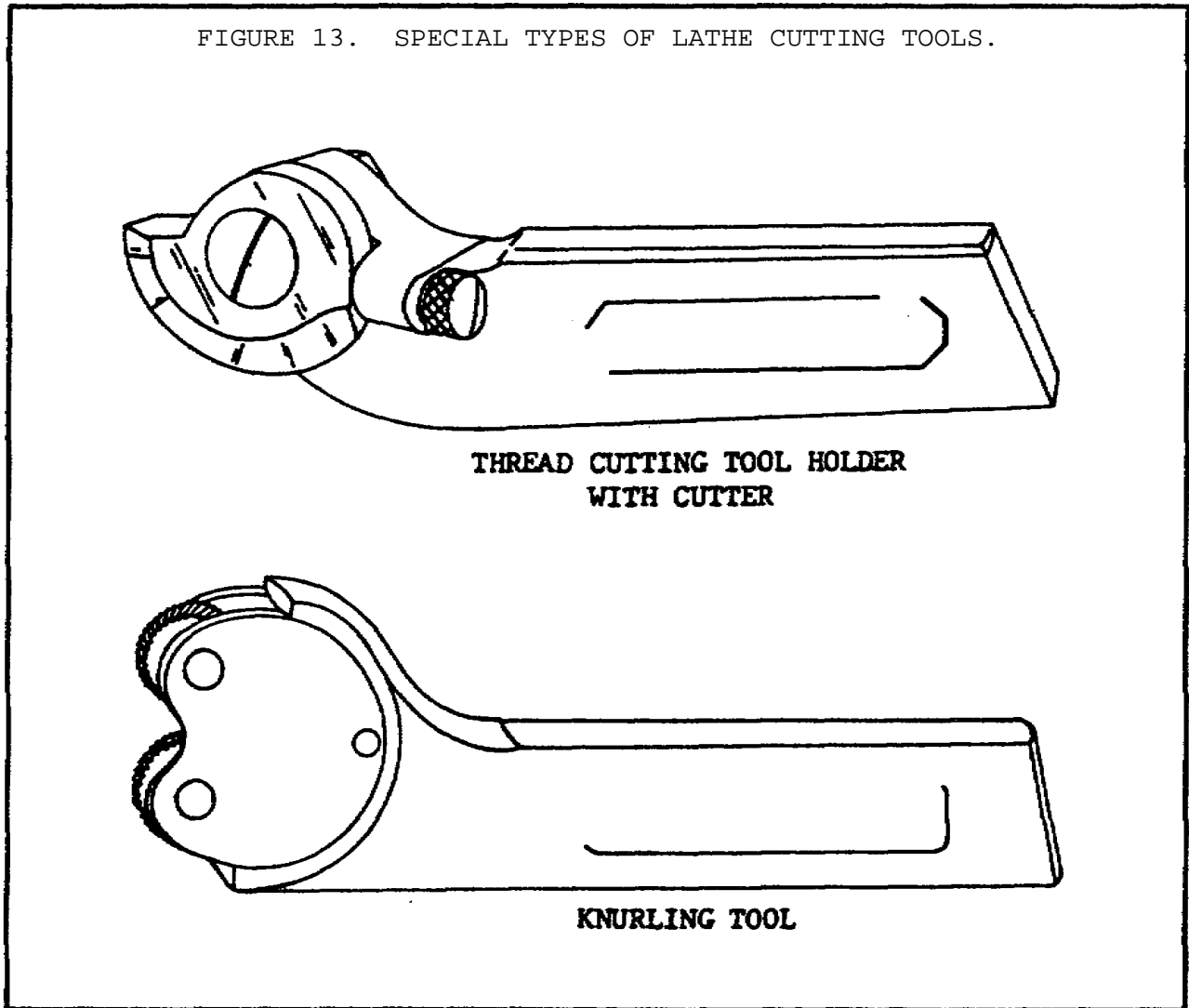
this bit is ground flat and has clearance ground on both sides so that it will cut on both sides. For American (National) Standard screw threads, the bit is ground with a flat at the nose to cut the flat root of the thread. The width of the flat at the nose is determined by the pitch of the screw thread that is to be cut.

(9) *Special Types Of Lathe Cutting Tools.* Besides the common cutter bits, special lathe operations and heavy production work require special types of cutting tools (figure 13 on the following page). Some of the more common special tools will be described in subparagraphs (a) through (e) below.

(a) *Tipped Cutter Bits.* Tungsten carbide, tantalum carbide, and oxide or ceramic tipped cutter bits are commonly used in production work where high speeds and heavy cuts are necessary, and where exceptional hard and tough materials are encountered. The tipped cutter bit generally has a shank size larger than the common cutter bit and is mounted in an openside cutting toolholder, a turret tool block, or directly in the toolpost of the lathe. Tipped cutter bits come in shapes for use in left-hand and right-hand turning, general purpose work and cutting threads.

(b) *The Threading Tool With Toolholder.* The threading tool (figure 13) with the toolholder is used where considerable thread cutting is to be accomplished. It is used in a specially designed toolholder which in turn mounts to the lathe toolpost. The threading tool has a formed cutter which needs to be ground on the top surface only for sharpening, the thread form being accurately shaped over a large arc of the tool. As the surface is worn away by grinding, the cutter can be rotated to the correct cutting position and secured there by the setscrew.

(c) *Knurling Tool.* The knurling tool (figure 13) consists of two cylindrical wheels, called knurls, which rotate in a specially designed toolholder. The knurls contain teeth which are rolled against the surface of the workpiece to form depressed patterns on the workpiece. The knurling tool accepts different pairs of knurls, each pair having a different pitch. The diamond pattern is



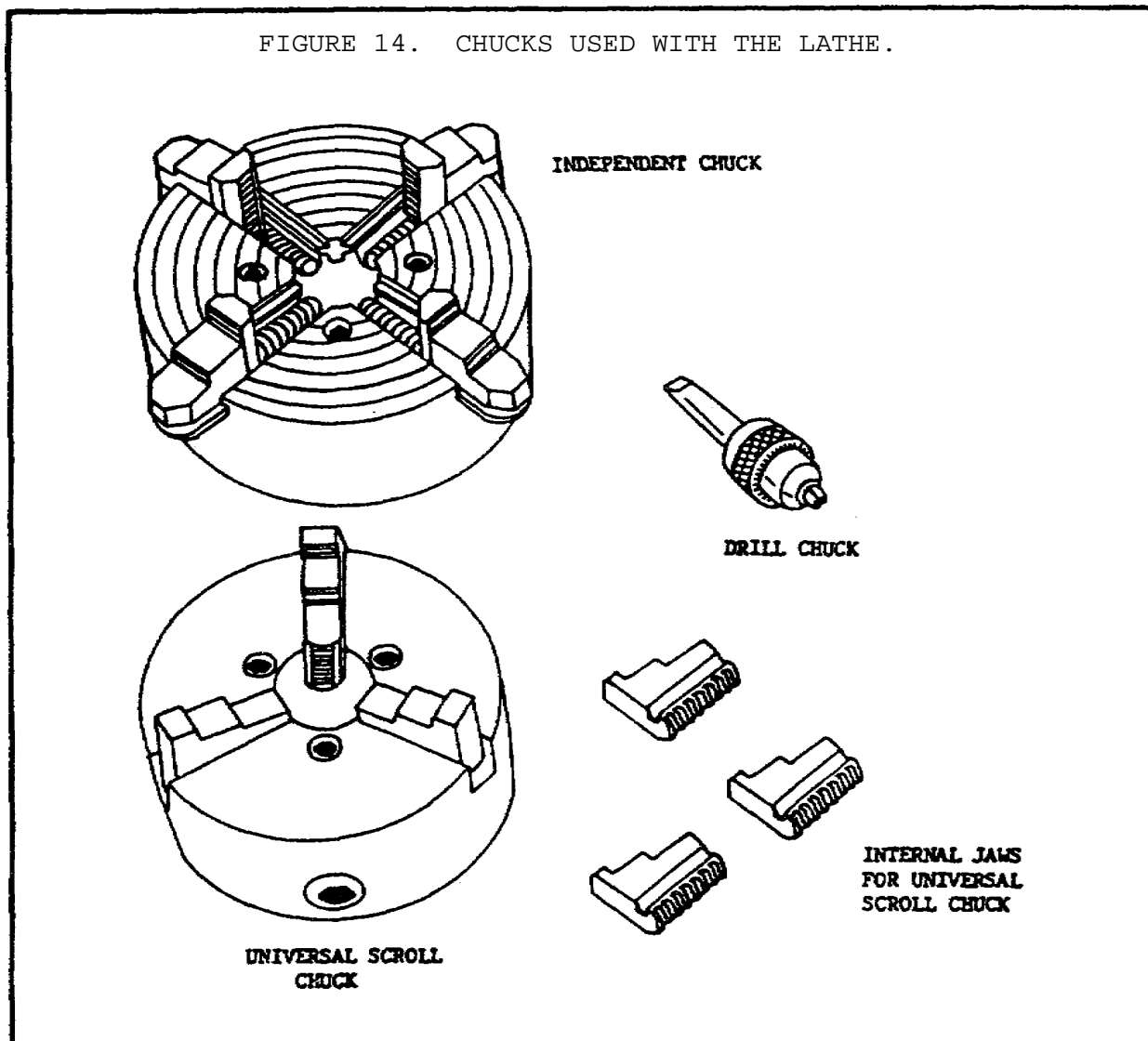
most widely used, and is generally supplied in three pitches: 14-pitch, 21-pitch, and 33-pitch to produce course, medium, and fine diamond patterns.

(d) *Boring Tools.* Boring tools are ground similar to left-hand turning cutter bits and thread cutter bits, but with more attention given to the end clearance angle to prevent the heel of the bit from rubbing against the surface of the bore. The boring cutter bit is clamped to a boring tool which in turn is supported in a boring toolholder that mounts to the lathe toolpost.

4. Lathe Accessories

a. Chucks.

(1) *General.* Workpieces are held to the headstock spindle of the lathe with chucks,



faceplates, or lathe centers. A lathe chuck is a device that exerts pressure on the workpiece to hold it secure to the headstock spindle or tailstock spindle. Commonly used with the lathe are the independent chuck, the universal scroll chuck, the combination chuck, the hollow headstock spindle chuck, the lathe tailstock chuck, the collet chuck, and the step chuck.

(2) *Independent Chuck.*

(a) The independent chuck (figure 14) generally has four jaws which are adjusted individually on the chuck face by means of adjusting screws. The chuck face is scribed with concentric circles which are used for rough alignment of the jaws when chucking round workpieces. The final adjustment is

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made by turning the workpiece slowly and using gages to determine its concentricity. The jaws are then readjusted as necessary to align the workpiece to desired tolerances.

(b) The jaws of the independent chuck may be used as in figure 14, or may be reversed so that the steps face in the opposite direction; thus, workpieces can be gripped either externally or internally. The independent chuck can be used to hold square, round, octagonal, or irregular shaped workpieces in either a concentric or eccentric position due to the independent operation of each jaw.

(c) Because of its versatility and capacity for fine adjustment, the independent chuck is commonly used for mounting workpieces that require extreme accuracy.

(3) *Universal Scroll Chuck.*

(a) The universal scroll chuck (figure 14 on the previous page) usually has three jaws which move in unison as an adjusting pinion is rotated. The advantage of the universal scroll chuck is its ease of operation in centering the work for concentric turning. This chuck is not as accurate as the independent chuck but, when in good condition, it will center the work automatically within 0.003 of an inch of complete accuracy.

(b) The jaws are moved simultaneously within the chuck by means of a scroll or spiral threaded plate. The jaws are threaded to the plate and move an equal distance inward or outward as the scroll is rotated by means of the adjusting pinion. Since the jaws are individually aligned on the scroll, the jaws cannot be reversed. However, the chuck is usually supplied with two sets of jaws which can be interchanged.

(c) The universal scroll chuck can be used to hold and automatically center round or hexagonal workpieces. Having only three jaws, the chuck cannot be used effectively to hold square, octagonal, or irregular shapes.

(4) *Combination Chuck.* A combination chuck combines the features of the independent chuck and the universal scroll chuck and can have either

three or four jaws. The jaws can be moved in unison on a scroll for automatic centering or can be moved individually if desired by separate adjusting screws.

(5) *Drill Chuck*. The drill chuck is a small universal-type chuck which can be used in either the headstock spindle or in the tailstock for holding straight-shank drills, reamers, taps, or small-diameter workpieces. The drill chuck has three or four hardened steel jaws which are moved together or apart by adjusting a tapered sleeve within which they are contained. The drill chuck is capable of centering tools and small-diameter workpieces to within 0.002 or 0.003 of an inch when firmly tightened.

(6) *Hollow Headstock Spindle Chuck*. The hollow headstock spindle chuck is similar to a drill chuck but is hollow. It is provided with threads to screw it onto the headstock spindle nose. This chuck can be used to hold rods, tubes, or bars which are passed through the headstock spindle. It is generally capable of centering workpieces to an accuracy of 0.002 of an inch.

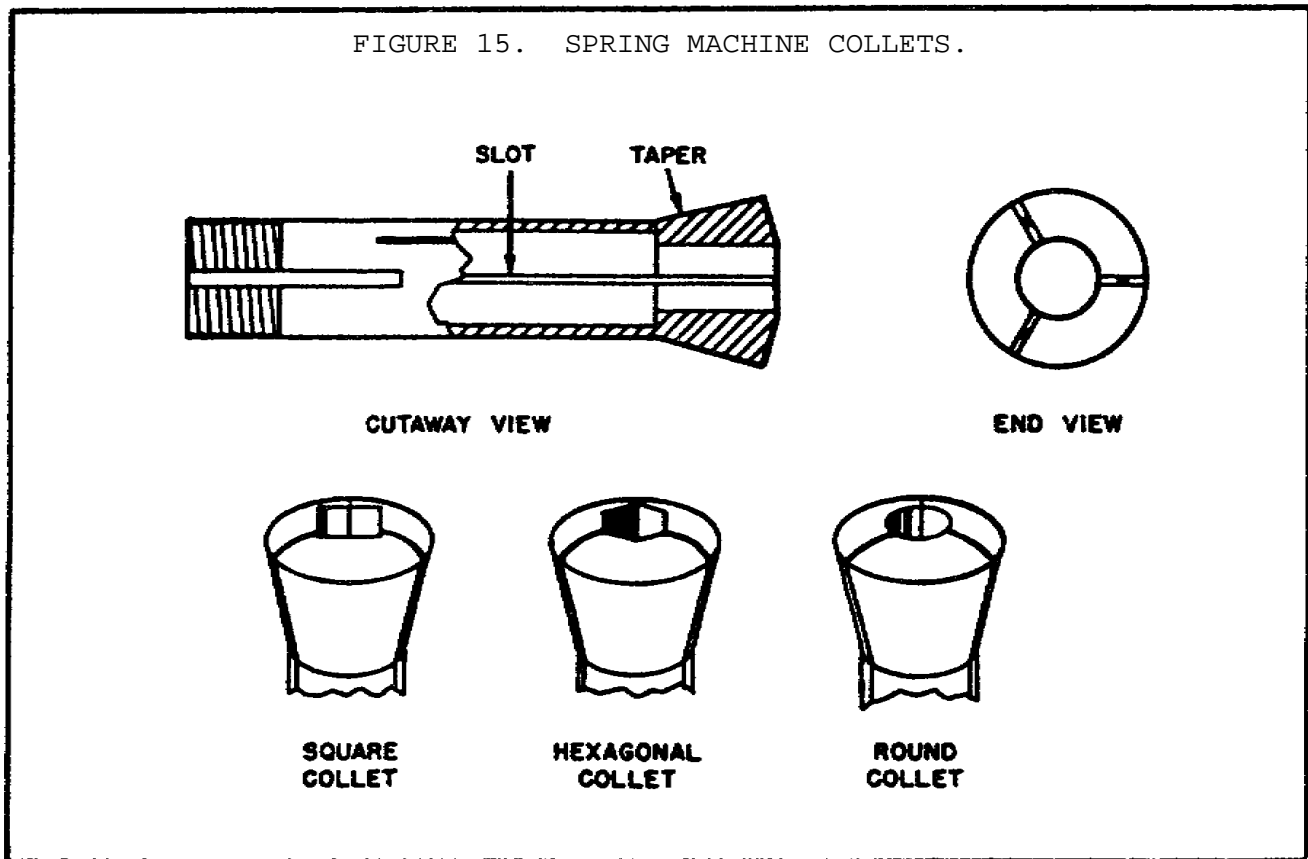
(7) *Collet Chuck*.

(a) The collet chuck is the most accurate means of holding small workpieces in the lathe. The collet chuck consists of a spring machine collet and a collet attachment which secures and regulates the collet on the headstock spindle of the lathe.

(b) The spring machine collet (figure 15 on the following page) is a thin metal bushing with an accurately machined bore and a tapered exterior. The collet has three lengthwise slots to permit its sides to be sprung slightly inward to grip the workpiece. To grip the workpiece accurately, the collet must be no more than 0.001 inch larger or smaller than the diameter of the piece to be chucked. For this reason, spring machine collets are generally supplied in sets with various capabilities in 1/16, 1/32, or 1/64 inch increments. For general purposes, the spring machine collets are limited in capacity to 1 inch in diameter.

(c) The collet attachment which, with the spring machine collet, forms the collet chuck and consists of a collet sleeve, a draw bar, and a

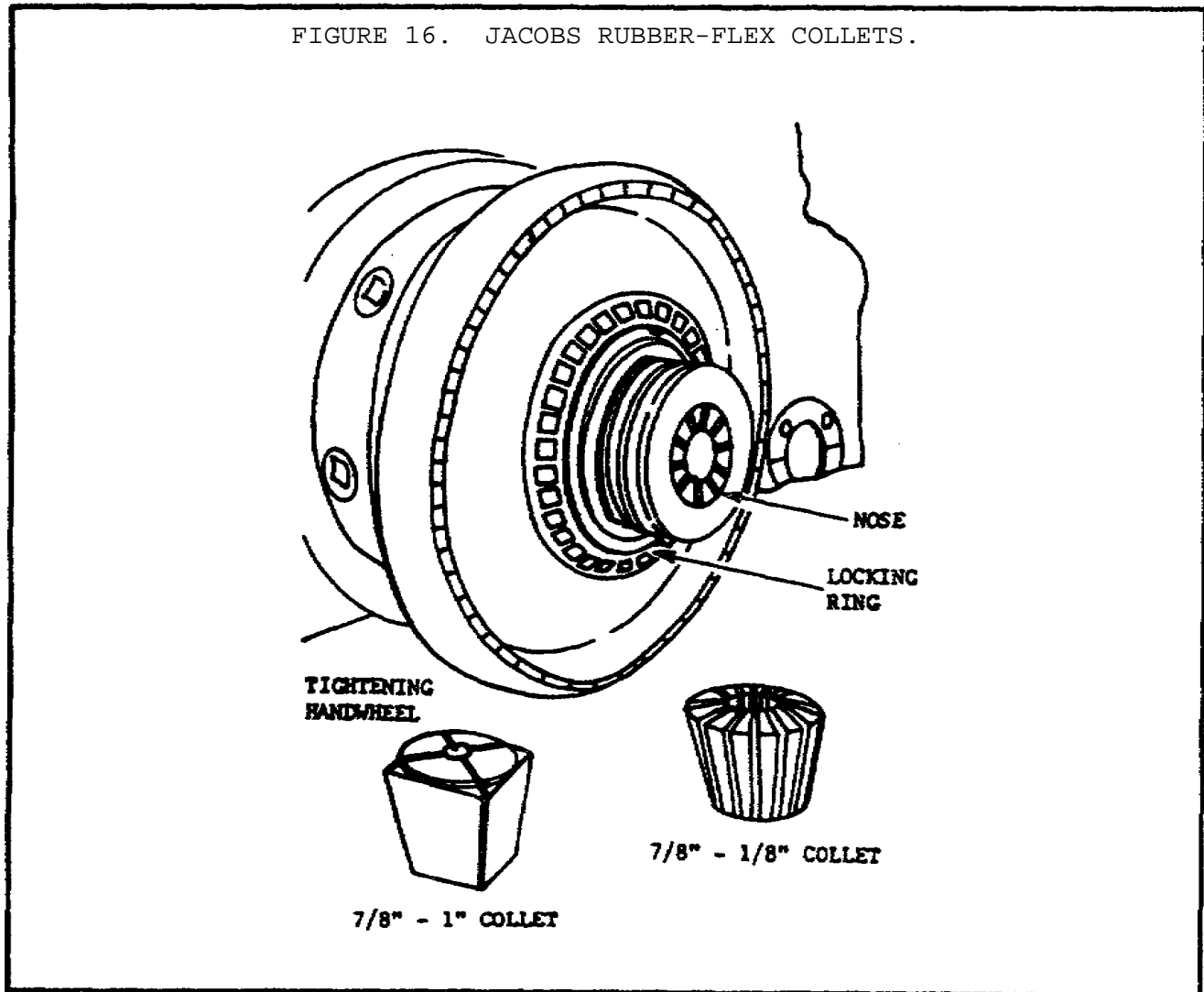
handwheel or hand lever to move the draw bar. The collet is fitted to the right end of the headstock spindle. The draw bar passes through the headstock spindle and is threaded to the spring machine collet. When the draw bar is rotated by means of the handwheel, the collet is pulled inward and the collet walls are cammed together by contact with the collet sleeve, tightening the chuck to the workpiece.



(d) Collet chucks are usually standard equipment on toolroom-type engine lathes and on horizontal turret lathes. Spring machine collets are available in different shapes in order to chuck square and hexagonal workpieces of small dimensions as well as round workpieces.

(8) *Jacobs Rubber-Flex Collets*. The rubber flex collet (figure 16 on the following page) is comprised of hardened alloy steel jaws bonded together with oil-resistant Hycar synthetic rubber. The collets have a range of 1/8 inch per collet and the gripping power and accuracy remain constant throughout the entire collet capacity. These

collets are designed for heavy-duty turning and possess 2 to 4 times the grip of conventional split steel type collets.



(9) *Step Chuck*. The step chuck is a variation of the collet chuck, but is intended for accurate holding of workpieces larger than 1 inch in diameter. The step chuck consists of the handwheel or hand lever collet attachment and a step chuck machine collet in place of the regular spring machine collet. The step chuck machine collet, which is split into three sections like the spring machine collet, is threaded to the draw bar of the collet attachment. As the step chuck machine collet is drawn into the collet sleeve, the three sections of the collet are cammed against the workpiece by an inside taper in the collet sleeve. The step chuck is supplied in 2, 3, 4, and 5 inch sizes, the size indicating the maximum diameter of

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the workpieces that can be supported. The step chuck machine collets are furnished blank and machined on the lathe to the desired step diameter.

(10) *Lathe Tailstock Chuck.* The lathe tailstock chuck is a device designed to support the ends of the workpieces in the tailstock when a lathe center cannot be conveniently used. The chuck has a taper arbor that fits the lathe tailstock spindle. The three bronze self-centering jaws of the chuck will accurately close upon the workpieces that are between 1/4 and 1 inch in diameter. The bronze jaws provide a good bearing surface for the workpiece. The jaws are adjusted to the diameter of the workpiece and then locked in place.

b. *Lathe Faceplates.*

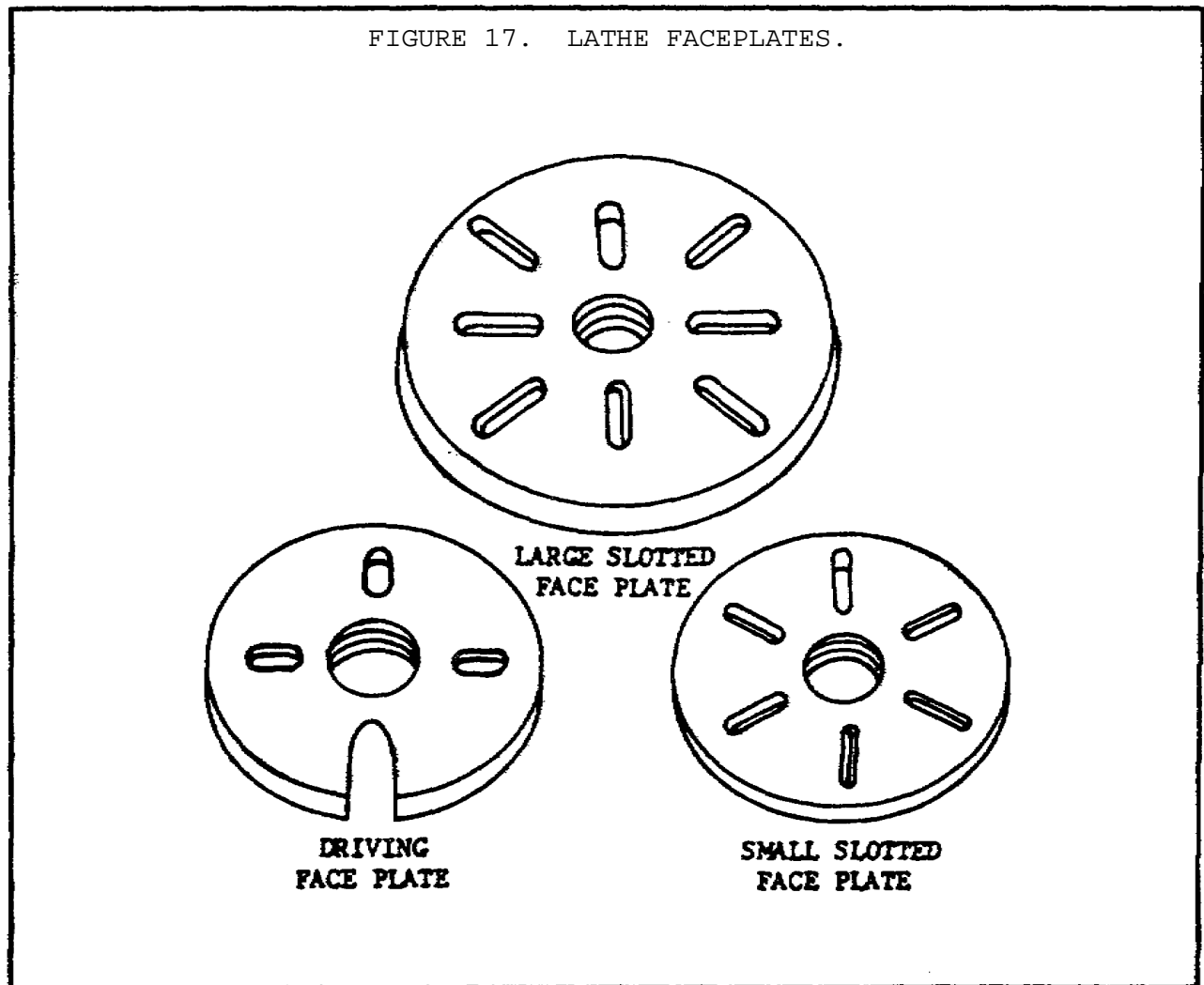
(1) A lathe faceplate (figure 17 on the following page) is a flat, round plate that threads to the headstock spindle of the lathe. The faceplate is used for clamping and machining irregularly-shaped workpieces that cannot be successfully held by chucks or mounted between centers. The workpiece is either attached to the faceplate using angle plates or brackets, or is bolted directly to the plate. Radial T-slots in the faceplate surface facilitate mounting workpieces. The faceplate is valuable for mounting workpieces in which an eccentric hole or projection is to be machined. The number of applications of the faceplate depends upon the ingenuity of the machinist.

(2) A small faceplate, known as a driving faceplate, is used to drive the lathe dog for workpieces mounted between centers. The driving faceplate usually has fewer T-slots than the larger faceplates. When the workpiece is supported between centers, a lathe dog is fastened to the workpiece and engaged in a slot of the driving faceplate.

c. *Lathe Centers.*

(1) *General.* Lathe centers (figure 18 on page 39) are the most common devices for supporting workpieces in a lathe. Most lathe centers have a tapered point with a 60° included angle to fit the workpiece holes with the same angle. The workpiece is supported between two centers, one in the

FIGURE 17. LATHE FACEPLATES.



headstock spindle and one in the tailstock spindle. Centers for lathe work have standard tapered shanks that fit into the tailstock directly and into the headstock spindle, using a center sleeve to convert the larger bore of the spindle to the smaller taper size of the lathe center. The centers are referred to as live centers or dead centers, depending upon whether they move with the workpiece or remain stationary. The most common types of centers are described below.

(2) *Male Center.* The male center or plain center is the type used in pairs for most general lathe turning operations. The point is ground to a 60° cone angle. When used in the headstock spindle, where it revolves with the workpiece, it is commonly called a live center. When used in the tailstock spindle, where it remains stationary when the workpiece is turning, it is called a dead

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center. Dead centers are always hard and must be lubricated very often to prevent overheating.

(3) *Pipe Center*. The pipe center is very similar to the male center, but its cone is ground to a greater angle and is larger in size. It is used for holding pipe and tubing in the lathe while they are being machined.

(4) *Female Center*. The female center is conically bored at the tip and is used to support workpieces that are pointed at the end.

(5) *Half-Male Center*. The half-male center is a male center that has a portion of the 60° cone cut away. The half-male center is used as a deadcenter in the tailstock where complete facing is to be performed. The cutaway portion of the center faces the cutting tool and provides the necessary clearance for the tool when facing the surface immediately around the drilled center in the workpiece.

(6) *V-Center*. The V-center is used to support round workpieces at right angles to the lathe axis for special operations such as drilling or reaming.

d. *Lathe Dogs*.

(1) Lathe dogs (figure 19 on page 39) are cast metal devices used in conjunction with a driving plate or a faceplate to provide a firm connection between the headstock spindle and the workpiece that is mounted between centers. This firm connection permits the workpiece to be driven at the same speed as the spindle under the strain of cutting. Frictional contact alone, between the live center and the workpiece, is not sufficient to drive the workpiece. Three common types of lathe dogs are illustrated in figure 19. Lathe dogs may have bent tails or straight tails. When the bent tail dogs are used, the tail fits into a slot of the driving face plate. When straight tail dogs are used, the tail bears against a stud projecting from the faceplate.

(2) The bent tail lathe dog with a headless setscrew is considered safer than the dog with the square head screw because the headless setscrew reduces the danger of the dog catching in the operator's clothing and causing an accident.

FIGURE 18. TYPES OF LATHE CENTERS.

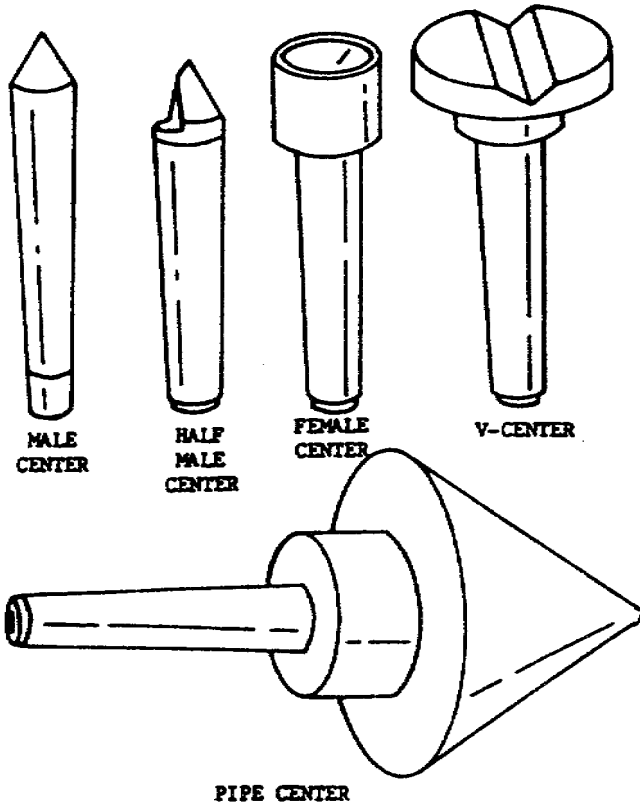
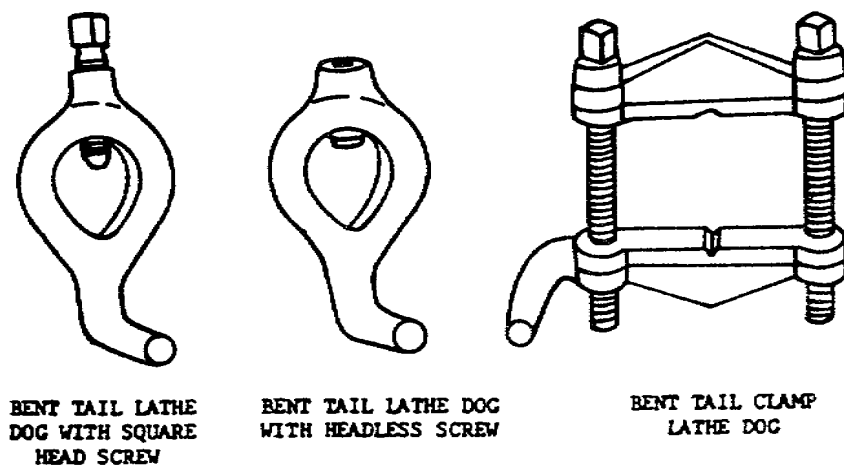


FIGURE 19. COMMON TYPES OF LATHE DOGS.



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(3) The bent tail clamp lathe dog is used primarily for holding rectangular workpieces.

e. *Mandrels.*

(1) *General.* A workpiece that cannot be held between centers because its axis has been drilled or bored, and which is not suitable for holding in a chuck or against a faceplate, is usually machined on a mandrel. A mandrel is a tapered axle pressed into the bore of the workpiece to support it between centers. A mandrel should not be confused with an arbor, which is a similar device used for holding tools rather than workpieces. To prevent damage to the work, the mandrel should always be oiled before being forced into the hole. When turning work on a mandrel, feed the cutting tool toward the large end of the mandrel, which should be nearest the headstock of the lathe.

(2) *Solid Machine Mandrel.* A solid machine mandrel is generally made from hardened steel and is ground to a slight taper ranging from 0.0005 to 0.0006 inch per inch. It has a very accurately countersunk center at each end for mounting the workpiece between centers. The ends of the mandrel are smaller than the body and have machined flats for the lathe dog to grip. The size of the solid mandrel is always stamped on the large end of the taper.

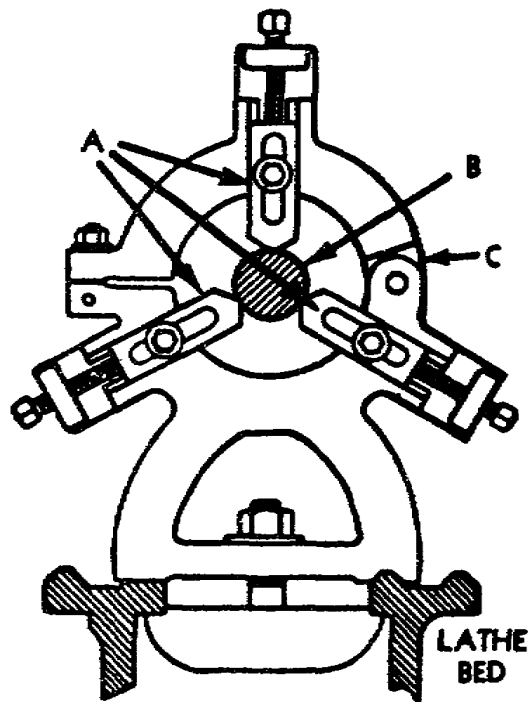
(3) *Expansion Mandrel.* An expansion mandrel is used to hold work that is reamed or bored to a nonstandard size. The expansion mandrel is composed of two parts: a tapered pin that has a taper of approximately 1/16 of an inch for each inch of length and an outer split shell that is tapered to fit the pin. The split shell is placed in the workpiece and the tapered pin is forced into the shell, causing it to expand until it properly holds the workpiece. Since solid machine mandrels have a very slight taper, they are limited to a workpiece with specific inside diameters. An expansion mandrel will not accept workpieces having a greater range of sizes. The expansion mandrel is, in effect, a chuck arranged so that the grips can be forced outward against the interior of the hole in the workpiece.

f. Rests.

(1) *General.* Workpieces often need extra support, especially long, thin workpieces that tend to spring away from the cutter bit. Two common supports or rests are the steady rest and the follower rest.

(2) *Steady Rest.* The steady rest or center rest, as it is also called (figure 20), is used to support long workpieces or shafts being machined between centers or for boring operations. It is also used for internal threading operations where the workpiece projects a considerable distance from the chuck or faceplate. The steady rest is clamped to the lathe bed at the desired location and supports the workpiece within three adjustable jaws. The rest prevents the workpiece from springing under cut, or sagging as a result of the otherwise unsupported weight.

FIGURE 20. STEADY/CENTER REST.

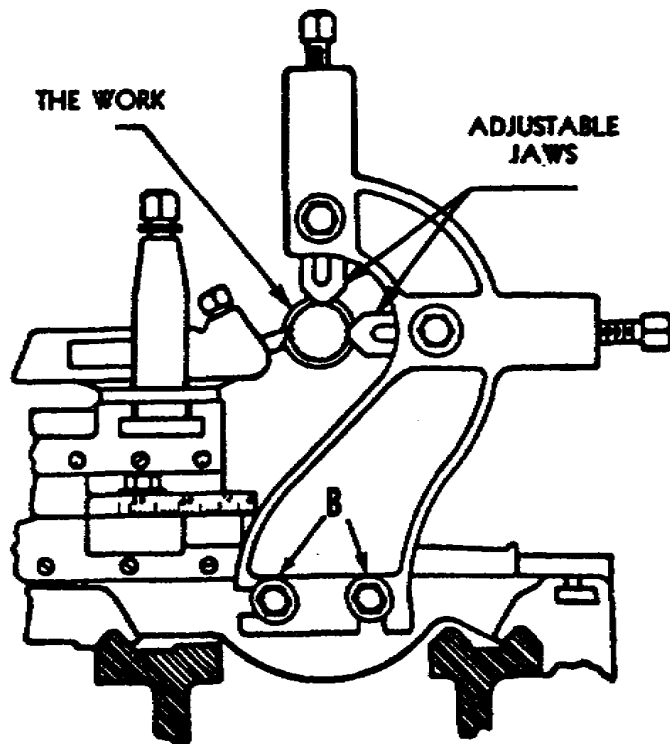


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The workpiece must be machined with a concentric bearing surface at the point where the steady rest is to be applied. The jaws must be carefully adjusted for proper alignment and locked in position. The area of contact must be lubricated frequently. The top section of the steady rest swings away from the bottom section to permit removal of the workpiece without disturbing the jaw setting.

(3) *Follower Rest.* The follower rest (figure 21) is used to back up a workpiece of small diameter to keep it from springing under the stress of the cutting operation. The follower rest gets its name because it follows the cutting tool along the workpiece. The follower rest has one or two jaws that bear directly on the finished diameter of the workpiece opposite and above the cutting tool. The rest is bolted to the lathe carriage so that it

FIGURE 21. FOLLOWER REST.

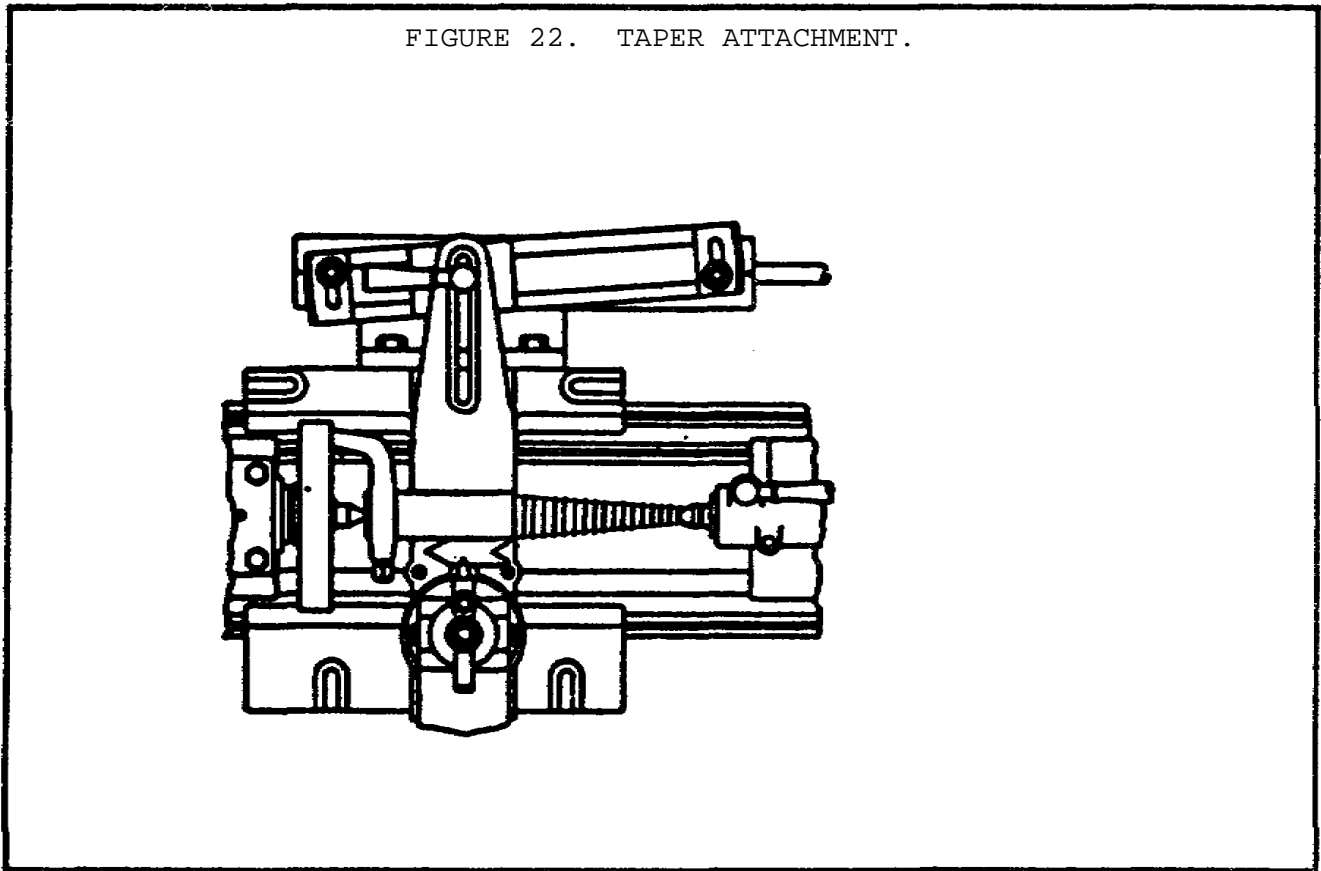


will follow the cutter bit and bear upon that portion of the workpiece that has just been turned. The cut must be started and continued for a short longitudinal distance before the follower rest is applied. The rest is generally used only for straight turning or threading long, thin workpieces.

g. *Taper Attachment.*

(1) The taper attachment (figure 22) is used for turning and boring tapers. It is bolted to the back of the carriage saddle. In operation, it is connected to the cross-slide so that it moves the cross-slide laterally as the carriage moves longitudinally. This action causes the cutting tool to move at an angle to the axis of the workpiece to produce a taper. A more detailed description on the operation of the taper attachment will be given on page 65, paragraphs 3(1)(a) through (d).

FIGURE 22. TAPER ATTACHMENT.

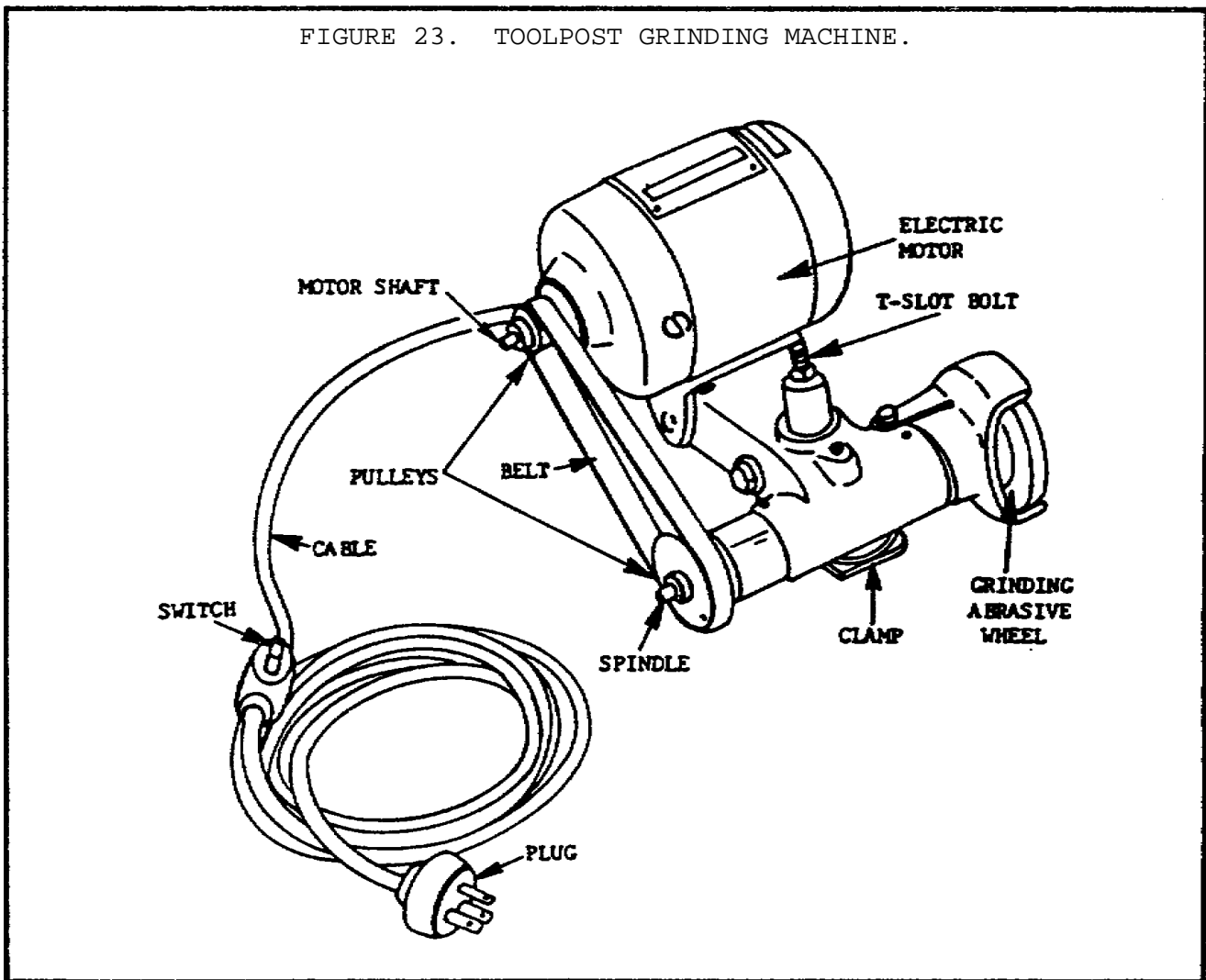


(2) The angle of the desired taper is set on the guide bar of the attachment, and the guide bar support is clamped to the lathe bed. Since the cross-slide is connected to a shoe that slides on

this guide bar, the tool follows along a line that is parallel to the guide bar and hence at an angle to the workpiece axis corresponding to the desired taper.

h. *Toolpost Grinding Machine.* The toolpost grinding machine (figure 23) is a machine tool attachment specially designed for cylindrical grinding operations on the lathe. It consists primarily of a 1/4 or 1/3 horsepower electric motor and a wheel spindle connected by means of pulleys and a belt. The machine fastens to the compound rest of the lathe with a T-slot bolt which fits into the T-slot of the compound rest in the same manner as the lathe toolpost. The toolpost grinding machine mounts grinding abrasive wheels ranging from 1/4 to 3 or 4 inches in diameter for internal and external grinding operations. A more detailed description of the toolpost grinding machine will be given in task 2, paragraph 2, beginning on page 77.

FIGURE 23. TOOLPOST GRINDING MACHINE.



i. *Milling and Grinding Attachment (Versa Mill)*. The milling and grinding attachment (figure 24 on the following page) is a versatile, self-powered attachment that fits to the carriage of the lathe. The attachment is used for milling slots, flats, or keyways on lathe mounted workpieces, for performing internal and external grinding operations, for drilling holes in the periphery of lathe-mounted workpieces, for reaming and boring operations, and for milling gear teeth and square tooth threads. The spindle of the milling and grinding lathe attachment is vertically adjustable, riding on four shafts and controlled by a screw and a hand wheel. Different head accessories adapt to the attachment for performing the variety of cutting functions mentioned previously. Task 2 will give more detailed information on this lathe attachment beginning on page 87, paragraph 4a(1).

5. *Safety Precautions For Lathes*

a. *General*. In machining operations, there is one sequence of events that one must always follow: SAFETY FIRST, ACCURACY SECOND, AND SPEED LAST. With this in mind, let's look at some of the more important safety precautions that should be observed before and during lathe operations.

b. Lathe accidents are usually caused by:

(1) Loose clothing snagging on the revolving workpiece, the chuck, or the workpiece.

(2) Flying chips entering the eye when turning cast iron or nonferrous metals.

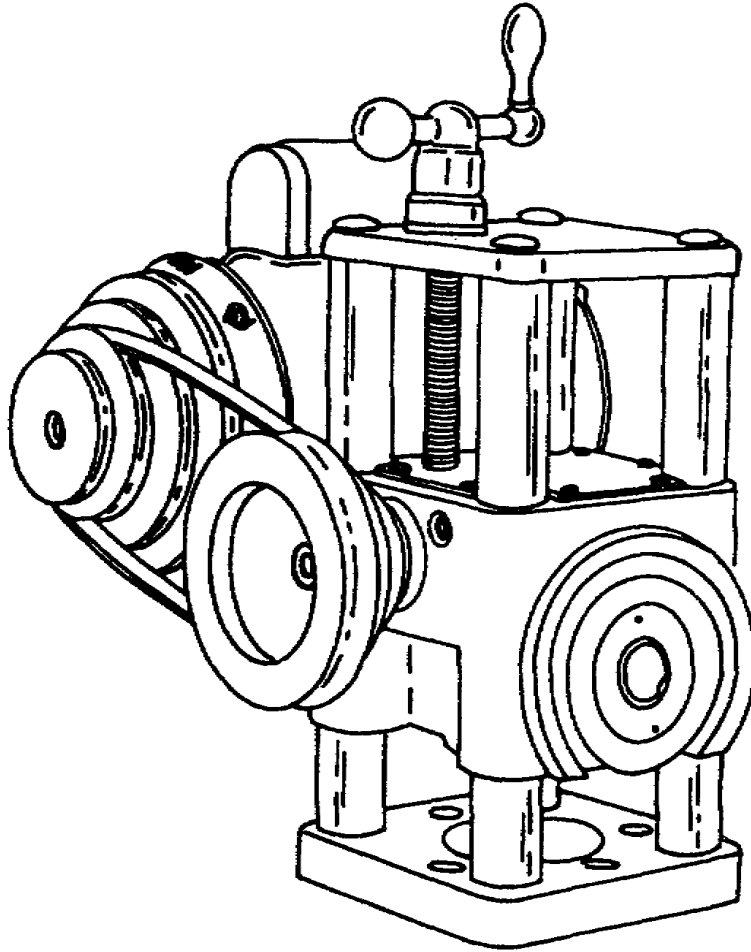
(3) Contact of the hands or arms with the lathe dog, chuck or workpiece.

c. The operator should prepare himself by rolling up his shirt sleeves and removing watches, rings, and other jewelry that might become caught while he is operating the machine.

d. The operator should be sure to wear safety glasses or a face shield of the approved type at all times when operating a lathe or when in the area of lathes that are in operation.

e. The operator should be sure that the work area is clear of obstructions that one might fall over or trip on.

FIGURE 24. MILLING AND GRINDING ATTACHMENT.



f. On turret lathes, care must be taken not to catch loose or torn clothing on a stock that is supported in the collet with chucks and extends beyond the headstock of the lathe.

g. If a coolant or cutting oil is used, the operator should take care when adjusting the splash pans to prevent the liquid from splashing on the floor. The cutting oil or coolant can make the floor beneath the lathe slippery and cause the operator to lose his balance and suffer injury.

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- h. The operator will keep the floor around the machine clear of oil or grease to prevent anyone from slipping and falling into the machine.
- i. The operator should use assistance when handling heavy or awkward parts, stock, or machine accessories. Never remove chips with your bare hands; a pair of pliers, a hook, or a brush should be used. (Stop the machine while removing the chips.)
- j. The operator should prevent long chips from being caught in the chuck by using good chip control procedures.
- k. The operator should never try to stop the machine with his hands or body.
- l. The operator will turn the machine off before talking to anyone.
- m. The operator should know how to stop the machine quickly if an emergency arises.
- n. The operator must be attentive, not only to the operation of the machine, but the events going on around it.
- o. The operator should be alert to the location of the cutting tool while taking measurements or making adjustments to the machine. He should see that the work and the cutting tools clear each other and that they are clamped securely before starting the machine.
- p. The operator will remove the centers and the cutting tools when not being used, and always observe the specific safety precautions posted for the machine in which you are operating.

6. *General Lathe Operations and Machining*

- a. *General.* To obtain good results on the lathe, a knowledge of the variable factors of speeds, feeds, cutting oils, and materials is necessary, as well as the mechanical application of the cutter bits to the workpiece. Cutting speeds, feeds, depth of cut, and cutting oils, if used, are different for each type of material and each operation; failure to keep these factors within proper limits may cause damage to the lathe or lathe tools, and can result in spoiling the

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workpiece. The methods of operation described in this lesson are general in nature. With experience, the machinist will be able to vary certain procedures with success for individual operations.

b. *Setting Up the Lathe.* Before starting a lathe machining operation, always ensure that the machine is set up for the job that is to be accomplished. If the workpiece is to be mounted between centers, check the alignment of the headstock center with the tailstock center (live or deadcenter) and make the necessary changes as needed. Ensure that the toolholder and the cutter bit are set at the proper height and angle. Check the workholding accessory to ensure that the workpiece is held securely. Use the center rest or follower rest to support long workpieces.

(1) The first step in preparing the centers is to see that they are accurately mounted in the headstock and tailstock spindles. The centers and the tapered holes in which they are fitted must be perfectly clean. Chips and dirt left on the contact surfaces will impair accuracy by preventing a perfect fit of the bearing surfaces. Be sure that there are no burrs in the spindle hole. If burrs are found, they must be removed by carefully scraping or reaming the surface with a Morse taper reamer. Burrs will produce the same inaccuracies as chips or dirt.

(2) Center points must be accurately finished to an included angle of 60° . Check the angle of the center with the use of a center gage. If the test shows that the point is not perfect, true the point in the lathe by taking a cut over the point with the compound rest set at 30° . The hardened tailstock center must be annealed before it can be machined or set up in the lathe and ground with the use of a toolpost grinder.

c. *Lathe Speeds and Feeds.*

(1) *General.* Determining the most advantageous feeds and speeds for a particular lathe operation depends on numerous factors such as the kind of material being worked on, the type of tool, the diameter and length of the workpiece, the type of cut desired (rough or finished), the cutting oil used, and the condition of the lathe being used.

(2) *Cutting Speed.*

(a) The cutting speed of a cutter bit is defined as the number of feet of workpiece surface, measured at the circumference, that pass the cutter bit in 1 minute. The cutting speed, expressed in feet per minute (fpm), must not be confused with the spindle speed of the lathe which is expressed in revolutions per minute (rpm). To obtain uniform cutting speed, the lathe spindle must be revolved faster for workpieces of small diameter and slower for workpieces of large diameters.

(b) The proper cutting speed for a given job depends upon the hardness of the material being worked on, the material of the cutter bit, and the feed and depth of cut to be used. Table 2 lists specific ranges of cutting speeds for straight turning and for threading under normal conditions. It is proper to start machining operations at these speeds and observe the effect on the cutter bit

TABLE 2. LATHE CUTTING SPEEDS FOR STRAIGHT TURNING AND THREADING.

Material	Straight turning speed (fpm) ¹	Threading speed (fpm) ¹
Aluminum.....	200 to 300..	50
Brass, yellow.....	150 to 200..	50
Bronze, soft.....	80 to 100..	30
Bronze, hard.....	30 to 80..	20
Cast iron.....	50 to 80..	25
Copper.....	60 to 80..	25
Monel metal.....	100 to 120..	35
Steel, high carbon (tool).....	35 to 40..	15
Steel, low carbon.....	80 to 100..	35
Steel, medium carbon.....	60 to 80..	25
Steel, stainless.....	40 to 50..	15

¹ The speeds are based on the use of high-speed steel cutter bits. These speeds may be increased 25 to 50 percent, if a cutting oil is used. If stellite or carbide-tipped cutter bits are used, speeds may be 2 or 3 times as high as those given for high-speed steel cutter bits. If carbon-steel cutter bits are used, the speed should be reduced by about 25 percent.

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and workpiece. If the cutter bit does not cut satisfactorily, the speed should be reduced. Carbon steel tools, when used, require a reduction in speed because they cannot withstand the heat produced as a result of high-speed turning. Carbide-tipped tools, however, will stand speeds in excess of those recommended for high-speed steel tools. The feed and depth of cut should be average as described in paragraphs (c) and (d) below, for the recommended speeds in table 2. If it desired to increase either the feed or the depth of cut, the cutting speed should be proportionally reduced to prevent overheating and excessive cutter bit wear.

(c) To determine the rotational speed necessary to produce a given cutting speed, it is necessary to know the diameter of the workpiece to be cut. To calculate the spindle speed, knowing the diameter of the workpiece, use the following formula:

$$\text{rpm} = \frac{\text{cs} \times 12}{\pi \times D}$$

Where, rpm = revolution per minute (spindle speed)

cs = cutting speed (feet per minute)

12 = constant (inches per foot)

π = 3.1416 (constant)

D = diameter of workpiece (in inches)

The formula above can be made into a simpler version by the process of cancellation, where the constant of 3.1416 is divided into the constant of 12, thus eliminating one step when solving the problem using this formula.

$$\text{rpm} = \frac{\text{cs} \times \frac{3.8195}{\cancel{3.1416}} \times \cancel{12}}{D}$$

The resulting formula would appear as:

$$\text{rpm} = \frac{\text{cs} \times 3.8195}{D}$$

The formula can be condensed into an even simpler one by rounding 3.8195 to the next nearest whole number, which in this instance would be the number 4.

$$\text{rpm} = \frac{\text{cs} \times 4}{D}$$

Where, rpm = revolutions per minute (spindle speed)
 cs = cutting speed (feet per minute)
 D = diameter of the workpiece (in inches)
 4 = constant (derived from process of cancellation and rounded to the whole number).

This method is a short cut for finding rpm. The results obtained from its use are accurate enough for practical purposes. When we consider all the variable factors which enter into the choice of the best cutting speed, formulas giving exact answers have no significance in practice. For example, if a 2-inch diameter workpiece is to be cut at the rate of 120 feet per minute, the spindle speed is calculated as follows:

$$\begin{aligned} \text{rpm} &= \frac{\text{cs} \times 12}{\pi \times D} \\ \text{rpm} &= \frac{120 \times 12}{3.1416 \times 2} \\ \text{rpm} &= \frac{1440}{6.2832} \\ \text{rpm} &= 229.1825 \text{ or } 229 \text{ rpm} \end{aligned}$$

or, using the condensed formula:

$$\text{rpm} = \frac{\text{cs} \times 4}{D}$$

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$$\text{rpm} = \frac{120 \times 4}{2}$$

$$\text{rpm} = 240$$

Spindle speeds for drills and other rotating cutters can be determined using the same formula by substituting the cutter diameter of the drill or cutter for the diameter of the workpiece. Table 2 on page 49 may be used to save time when computing rotational spindle speeds for common cutting speeds and common workpiece diameters.

(d) Another factor to consider when selecting cutting speed includes the use of cutting oils, the length and diameter of the workpiece, and the condition of the lathe. If a large stream of proper cutting oil is applied to the workpiece at the cutter bit, the cutting speed can be increased as much as 40 percent. If the diameter of the workpiece is small and its length is great enough to set up vibrations due to the speed, a poor finish will result; to correct this condition, the speed must necessarily be reduced. The lathe may also be in poor condition so that high speeds will cause harmful vibrations.

(e) The technical manual for the lathe being used should be consulted for instructions in setting spindle speed for operation. If a desired spindle speed is not available on the lathe, select a speed nearest that which is desired, generally the first slower speed that is available. For efficient lathe operation, the machinist should be able to recognize too slow a speed as well as too fast a speed.

(3) *Feed*.

(a) *General*. Feed is the term applied to the distance the cutter bit advances for each revolution of the workpiece. Feed is specified in inches per revolution. Since the best feed depends upon a number of factors such as depth of cut, type of material, size of workpiece, and condition of the lathe, it is difficult to list the best feed for the different materials.

(b) *Rough Cuts.* For rough cuts, the feed may be relatively heavy since the surface need not be exceptionally smooth. For most materials, the feed for rough cuts should be 0.010 to 0.020 inch per revolution. The feed may be 0.040 inch on large lathes with larger diameter workpieces. Care must be taken when turning slender workpieces as a heavy cut may bend the piece, ruining it. In this case, it is best to reduce the feed to 0.008 - 0.015 inch per revolution.

(c) *Finish Cuts.* For finish cuts, a light feed is necessary since a heavy feed causes a built-up edge to form on the surface, which produces a poor finish. If a large amount of stock is to be removed, it is advisable to take one or more roughing cuts and then take light finishing cuts at relatively high speeds. For most materials, the feed for finishing cuts should be 0.003 to 0.010 inch per revolution. An exception is finishing soft metal like aluminum where a broad nose cutter bit is used at feeds as great as 1/8 to 1/2 inch per revolution.

(4) *Depth of Cut.*

(a) *General.* The depth of cut regulates the reduction in the diameter of the workpiece for each longitudinal traverse of the cutter bit. The workpiece diameter is reduced by twice the depth of the cut in each complete traverse of the cutter bit. Generally, the deeper the cut, the slower the speed, since a deep cut requires more power.

(b) *Rough Cuts.* The depth of the cut for roughing is generally five to ten times deeper than the feed. The reason for this is that more of the cutting edge of the cutter bit is in contact with the workpiece for the amount of metal being removed permitting a greater speed to be used. For roughing with feeds of from 0.010 to 0.020 inch per revolution, the depth of cut should be between 3/16 and 1/4 inch. Deeper cuts up to 1/2 inch can be taken but the feed should be proportionately reduced. A heavy cut may cause the workpiece and the cutter bit to chatter; in this case the depth of cut should be reduced.

(c) *Finish Cuts.* Finish cuts are generally very light; therefore, the cutting speed can be increased since the chip is thin.

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d. *Cutting Oils.*

(1) *General.* The chief purpose of cutting oil is to cool the cutter bit and the workpiece. The name "coolant" is often given to the oil. A cutter bit will last longer and will be capable of withstanding greater speeds without overheating when a cutting oil is used. A cutting oil also helps lubricate the cutter bits, improves the finish of the workpiece, guards against rusting, and washes away chips from the cutting area.

(2) *Use.* In production operations, the practice is to flood the workpiece and the cutter bit with cutting oil in order to obtain the full benefit of its use. For effective cooling, it is important that the oil be directed at the exact point of the cutter bit contact. A large stream at low velocity is preferred to a small stream at high velocity. In small shops where pump equipment is not available, cutting oils are used only for finishing and delicate operations. It is general practice in this case to apply the cutting oil only when actually required.

(3) *Types of Cutting Oils.* Cutting oils most commonly used and their general applications are described in (a) through (g) below. Cutting oils for specific lathe operations are listed in Table 3 on page 56.

(a) *Lard Oil.* Pure lard oil is one of the oldest and best cutting oils. It is especially good for thread cutting, tapping, deep hole drilling, and reaming. Lard oil has a high degree of adhesion or oiliness, a relatively high specific heat, and its fluidity changes slightly with the temperature. It is an excellent rust preventive and produces a smooth finish on the workpiece. Because lard oil is expensive, it is seldom used in a pure state but is combined with other ingredients to form good cutting oil mixtures.

(b) *Mineral Oil.* Mineral oils are petroleum based oils that range in viscosity from kerosene to light paraffin oils. Mineral oil is very stable and does not develop disagreeable odors like lard oil; however, it lacks some of the good qualities of lard oil such as adhesion, oiliness, and high specific heat. Because it is relatively inexpensive, it is mixed with lard oil or other chemicals to provide cutting oils with desirable

characteristics. Two mineral oils, kerosene and turpentine, are often used alone for machining aluminum and magnesium. Paraffin oil is used, alone or with lard oil, for machining copper and brass.

(c) *Mineral-Lard Cutting Mixture.* Various mixtures of mineral oils and lard oil are used to make cutting oils which combine the good points of both ingredients but prove more economical and often as effective as lard oil.

(d) *Sulfurized-Fatty-Mineral Oil.* Most good cutting oils contain mineral oil and lard oil with various amounts of sulfur and chlorine, which give the oils good antiweld properties and promote free machining. These oils play an important part in present-day machining because they provide good finishes on most materials and aid the cutting of tough materials.

(e) *Soluble Cutting Oils.* Water is an excellent cooling medium but has little lubricating value and hastens rust and corrosion. Therefore, mineral oils or lard oils which are mixable with water are often mixed with water to form a cutting oil. Soluble oil and water has lubricating qualities depending upon the strength of the solution. Generally, soluble oil and water is used for rough cutting where quick dissipation of heat is most important. Borax and trisodium phosphate are sometimes added to the solution to improve its corrosion resistance.

(f) *Soda-Water Mixtures.* Salts such as soda ash and trisodium phosphate are sometimes added to water to help control rust. This mixture is the cheapest of all coolants and has practically no lubricating value. Lard oil and soap in small quantities are sometimes added to the mixture to improve its lubricating qualities. Generally, soda water is used only where cooling is the prime consideration and lubrication is secondary. It is especially suitable in reaming and threading operations on cast iron where a better finish is desired.

(g) *White Lead And Lard Oil Mixture.* White lead can be mixed with either lard oil or mineral oil to form a cutting oil which is especially suitable for difficult machining of very hard metals.

TABLE 3. CUTTING OILS FOR LATHE OPERATIONS.

Material	Cutting Oil		
	Heavy cutting	Light cutting	Threading
Aluminum.....	Dry; soluble cutting oil.	Dry.....	Mineral-fatty-blend cutting oil.
Brass.....	Dry; soluble cutting oil.	Dry.....	Sulfurized-fatty-mineral cutting oil.
Bronze.....	Soluble cutting oil.	Soluble cutting oil.	Sulfur-treated mineral-lard cutting oil.
Cast iron.....	Dry.....	Dry.....	Sulfurized-fatty-mineral cutting oil.
Copper.....	Dry; mineral-fatty-blend cutting oil.	Dry; mineral-fatty-blend cutting oil.	Mineral-fatty-blend cutting oil.
Monel metal.....	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Pure lard cutting oil; sulfurized-fatty-mineral cutting oil.
Steel, machine..	Soluble cutting oil	Mineral-fatty-blend cutting oil; soluble cutting oil.	Sulfurized-fatty-mineral cutting oil.
Steel, tool.....	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Pure lard cutting oil; sulfurized-fatty-mineral cutting oil.
Steel, stainless....	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Soluble cutting oil; sulfurized-fatty-mineral cutting oil.	Pure lard cutting oil; sulfurized-fatty-mineral cutting oil.

e. *Facing.*

(1) *General.* Facing is the square finishing of the ends of the workpiece and is often used to bring the piece to a specified length. In facing operations, the cutter bit does not traverse laterally (left or right) but cuts inward or outward from the axis of the piece. Facing of the ends is usually performed before turning operations.

(2) *Mounting the Workpiece For Facing.* The workpiece to be faced may be mounted between centers or in a lathe chuck. If the right end of the piece is to be faced and the piece is to be mounted between centers, a half-center is often used in the tailstock spindle. The half-center permits complete facing to the center hole without interference with the center. With the piece mounted between centers, the left end cannot be faced if a lathe dog is used. It is advisable to reverse the piece for this operation.

(3) *Proper Cutter Bit For Facing.* The right-hand facing cutter bit is used for facing the right end of the workpiece and for shoulders which face to the right. The left-hand facing cutter bit is used for facing the left end of the workpiece and for shoulders which face to the left.

(4) *Position of The Cutter Bit For Facing.* With the cutter bit positioned in the cutting toolholder, fasten the holder to the toolpost (figure 25 on page 59). Carefully adjust the holder so the cutting edge of the bit is exactly on the horizontal centerline of the workpiece. If the cutting edge is not on center, the end cannot be faced to the center of the piece and the rake and clearance angles will not be correct. Adjust the cutting edge of the cutter bit to a slight angle to the workpiece surface by adjusting the compound rest of the lathe.

(5) *Facing Operation.* For the first or roughing cut, set the cutter bit, subparagraph (4) above, and begin the cut as close as possible to the axis of the workpiece, feeding the bit outward, away from the axis (figure 25). Remove only enough metal to square the end over its entire surface. If the piece must be faced to a specific length, take two or more roughing cuts in the same manner, leaving a small amount of metal to be removed for the finishing cut. For the finishing cut, readjust the bit so that the cutting edge is set nearly flat against the workpiece surface, removing only a light, thin chip. The finishing can be taken in either direction, from the axis outward as in the roughing cut, or from the circumference of the workpiece inward toward the axis. In facing, care is needed to see that the bit does not contact the tailstock center.

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f. *Straight Turning.*

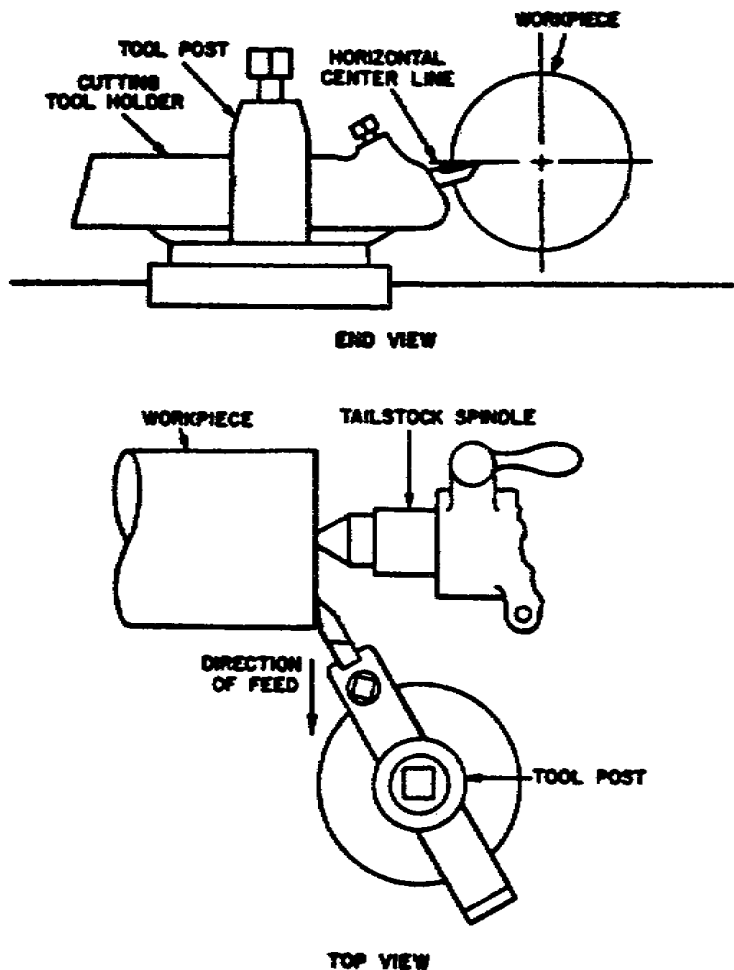
(1) *General.* Straight turning may be performed upon a workpiece supported in a chuck, but the majority of workpieces turned on an engine lathe are turned between centers. Turning is the removal of metal from the external surface of cylindrical workpieces using various types of cutter toolbits.

(2) *Mounting Workpieces For Straight Turning.* Lathe centers must be in good condition and carefully aligned if the turning operation is to be accurate. If necessary, regrind the centers and check their alignment. When turning the workpieces, considerable heat will be generated causing the workpiece to expand. Centers that are too tight may cause binding of the workpiece due to this expansion. The tailstock center or the deadcenter must be well lubricated to prevent the workpiece from overheating. The center hole and the tailstock center should be lubricated before the cutting operation with a mixture of white lead and motor oil. During the turning operation, feel the deadcenter frequently to determine whether lubrication or adjustment is necessary.

(3) *Proper Cutter Bits For Straight Turning.* Straight turning is accomplished with the left-hand turning cutter bit, the right-hand turning cutter bit, or the roundnose turning cutter bit. Wherever possible, the right-hand turning cutter bit or a roundnose bit ground for right-to-left turning is used and the bit is fed toward the headstock. If circumstances demand that the bit feed from left to right, such as in turning up to a shoulder, the left-hand cutter bit is used. The roundnose turning cutter bit is especially efficient for finishing cuts.

(4) *Position of Cutter Bit For Straight Turning.* The cutter bit should be locked in the cutting toolholder and the holder should be fixed to the toolpost so that the cutting edge of the bit touches the workpiece surface at about 5° above the horizontal centerline of the piece (figure 26 on page 60) since this position gives the bit a better cutting action. The distance above the center is governed by the diameter of the workpiece and the front clearance angle of the cutter bit. As a general rule, the point of contact of the cutting edge is raised $\frac{3}{64}$ inch above the center for each

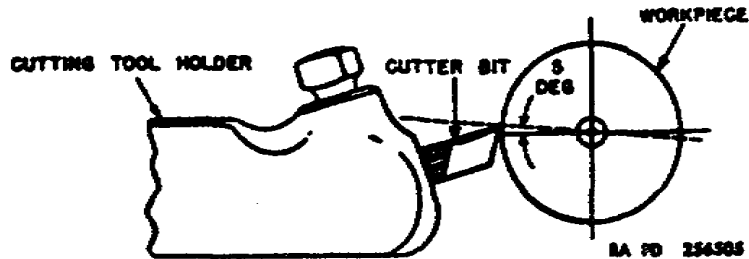
FIGURE 25. POSITION OF THE CUTTER BIT FOR FACING.



inch of the workpiece diameter. In a horizontal plane, the bit and the holder should be positioned at right angles to the workpiece axis or at a slight leading angle so that the bit will not dig into the workpiece if the bit or the toolholder should accidentally work loose.

(5) *Straight Turning Operation.* As a rule, the workpiece is turned down by a number of roughing cuts to a predetermined diameter which is within 1/32 to 1/64 inch of the diameter desired. The remaining metal is removed by a finish cut using a fine feed to produce a good surface. After taking the first roughing cut along the entire workpiece surface check the center alignment by measuring each end with calipers. If the ends are of

FIGURE 26. POSITION OF CUTTER BIT FOR STRAIGHT TURNING.



different diameters, the tailstock center is out of alignment with the headstock spindle and realignment is necessary. Continue cutting after correct alignment is made, stopping the lathe at intervals to check the tailstock center. After roughing, reverse the ends of the workpiece so that the area held by the lathe dog can be turned. When the piece is within 1/32 to 1/64 inch of the desired size, reduce the depth of cut, reduce the feed, increase the speed, and take light finishing cuts to the proper dimension. Measure the workpiece after each cut, with micrometer calipers. Reverse the piece again and, using shims under the lathe dog to prevent scoring of the machined surface, finish the other end of the workpiece.

NOTE

Remember that if the workpiece is turned smaller than the described size, it cannot be made larger and is ruined.

g. Shoulder Turning.

(1) *General.* It is frequently necessary to turn a workpiece so that it will have two or more diameters in its length. For example, a bar 12 inches long might be 3 inches in diameter for half its length, and 3 1/2 inches in diameter for the other half. It would therefore have an abrupt step

or shoulder 1/4 inch high that is 6 inches from the small end. The shoulder may be machined so that it forms a sharp corner with the small diameter, or a fillet may be formed so that the corner is slightly rounded instead of square.

(2) *Mounting Workpiece For Shoulder Turning.* The workpiece may be mounted in a chuck or between centers for straight turning.

(3) *Proper Cutter Bits For Shoulder Turning.* For turning the small diameter portion of the workpiece down to the desired size, a roundnose turning cutter bit is preferred. The shoulder is finished turned to size, using a facing cutter bit if a square shoulder is required, or with a roundnose turning cutter bit if a fillet is required. The roundnose cutter bit may be specially ground to produce a special size fillet if necessary. A parting cutter bit may be used at the shoulder location to mark the position of the shoulder and, in some cases, to provide an undercut or recess if a bearing is to be carried on the shoulder.

(4) *Shoulder Turning Operation.*

(a) The first important step in machining a circle is to locate the shoulder correctly. Usually, the position is marked by bluing the workpiece after it has been rough turned to the large diameter, accurately indicating the shoulder location with the hermaphrodite calipers (figure 27 on page 63).

(b) The small diameter portion of the workpiece is then turned down by a series of roughing cuts taken toward the shoulder. Take care to stop the traverse of the cutter bit about 1/32 inch before it reaches the scribed line; this 1/32 inch is important because it leaves sufficient metal on the shoulder to provide for facing operation after the smaller diameter portion has been turned to size.

(c) An alternate method of shoulder turning is to cut in at the shoulder mark with a parting tool. If this is done, be sure that the bit does not cut deeper than the required small diameter for square finished shoulders, or deeper than the small diameter less the radius of the intended fillet if a fillet is required. However, if the shoulder is to carry a bearing, it may be desirable that an

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 1

undercut or recess be left to assure a good fit (figure 27) The workpiece is then turned to size, stopping the traverse of the cutter bit at the recess.

(d) As in straight turning, the workpiece should be rough turned to within 1/32 to 1/64 inch of its finished diameter. The procedure described in the next paragraph should be followed for the finishing cut.

h. *Finish Turning.*

(1) *General.* When the workpiece has been rough turned to within about 1/32 inch of the finished size, take a finishing cut. A fine feed, the proper lubricant, and above all a keen-edged toolbit are necessary to produce a smooth finish. Measure carefully to be sure that the workpiece is being machined to the proper dimension. The lathe should be stopped whenever measurements are to be made.

(a) If the workpiece is to be finished to extreme close tolerances, wait until the piece is cool before taking the finish cut. If the finished cut is taken while the workpiece is still hot and slightly expanded, the workpiece will be undersize after it has cooled and contracted.

(b) If the workpiece is to be finished on a cylindrical grinder, leave the stock oversize to allow enough metal for the grinder to remove.

(c) Perhaps the most difficult operation for a beginner in machine work is to make accurate measurements. So much depends on the accuracy of the workpiece that one should make every effort in becoming proficient in the use of measuring instruments. During the use of the precision tools, one will develop a certain "feel" through experience. One should not become discouraged if their first efforts do not produce perfect results. To become proficient in taking measurements, one should practice taking measurements on pieces of known dimensions, such as gage (Jo) blocks.

(2) *Filletted Shoulder Finish.* To finish a filletted shoulder, use longitudinal feed and turn the small diameter up to the shoulder with a roundnose turning cutter bit positioned as shown in

FIGURE 27. LOCATION OF SHOULDER POSITION AND TYPES OF SHOULDER FORMATION.

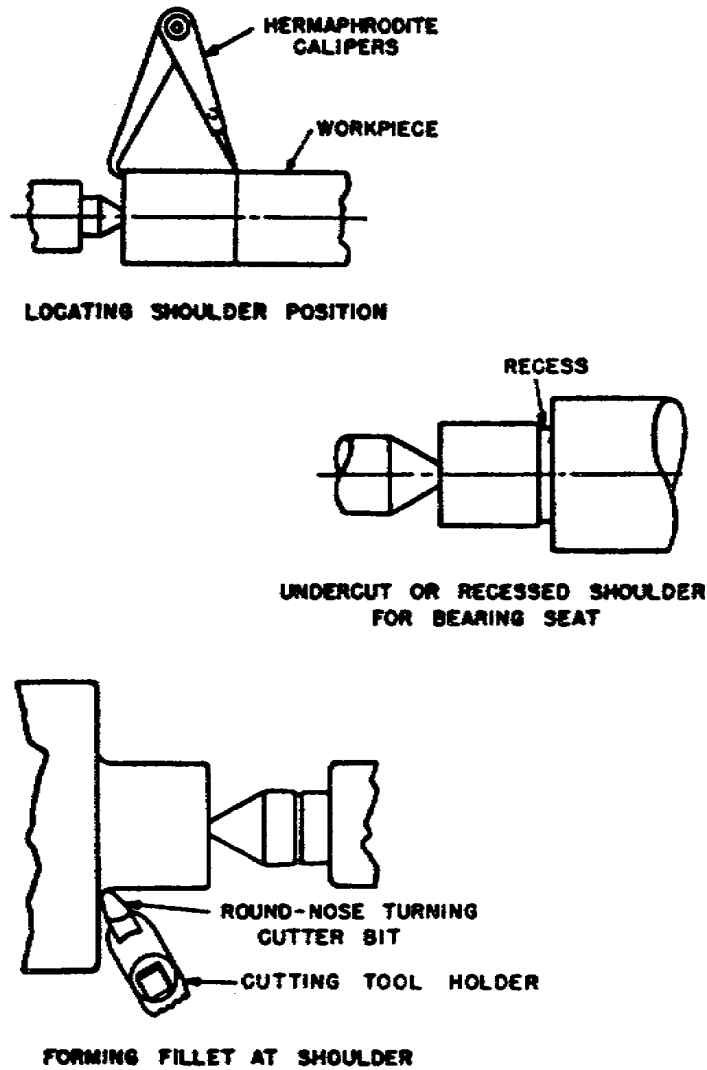


figure 27. Engage the crossfeed and allow the bit to face the shoulder, moving it outward from the axis.

(3) *Squared Shoulder Finish.* To finish a square shoulder, set the compound rest parallel to the ways of the lathe and use a facing cutter bit to cut out the fillet left in the corner by the roughing bit. Using longitudinal feed, finish the small diameter up to the finished size of the

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shoulder. Lock the carriage and use the compound rest to feed the bit the additional amount necessary to finish the workpiece to the proper length. Engage the crossfeed to carry the bit away from the small diameter and face the shoulder.

i. *Parting.*

(1) *General.* One of the methods of cutting off a piece of stock while it is held in a lathe is a process called parting. This process uses a specially shaped tool with a cutting edge similar to that of a square nose cutting tool. The parting tool is fed into the rotating workpiece, perpendicular to its axis, cutting a progressively deeper groove as the workpiece rotates. When the cutting edge of the tool gets to the center of the workpiece being parted, the workpiece drops off. Parting is used to cut off parts that have already been machined in the lathe, or to cut tubing and bar stock to their required lengths.

(2) *Parting Operation.*

(a) The workpiece to be parted should be mounted in a chuck. In cutting off stock, the setup of the tool should be made rigid. For the tool to have maximum strength, the length of the cutting portion of the blade that extends from the holder should be only slightly greater than half the diameter of the work that is to be parted.

(b) Place the end of the cutting edge of the parting tool exactly on the centerline of the lathe. To do this, place a center in the tailstock and align the cutting edge of the parting tool with the tip of the tailstock center. The workpiece should be held in the chuck jaws close to the point at which the parting is to occur. Always make the parting cut and feed the tool into the workpiece at right angles to the centerline of the workpiece. The carriage is clamped to the bed to prevent the tool from moving to the right or left when making a cut.

(c) The cutting speed is governed principally by the hardness of the metal to be turned, the type of steel of which the parting tool is made, the feed and depth of cut, the cooling medium used, the power and condition of the machine being used, and the skill of the operator. The recommended starting speed is a spindle speed about one-third

the speed used for conventional turning. When cutting off steel, keep the work flooded with oil. However, no oil is needed in cutting off cast iron.

(d) A power feed of approximately 0.002 inch per revolution may be used, although it is sometimes advisable to feed by hand, thereby retaining control of the cutter bit in case of emergency. The cutting edge is set on center when cutting off stock 1 inch or less in diameter and 1/16 inch above center for each additional inch in diameter. The tool must be lowered as the diameter is reduced, unless the center of the workpiece has been drilled out. Do not attempt to cut off work that is held between centers. It cannot be performed satisfactorily.

(3) *Chattering*. The rapid vibration of the tool and work, which is called chattering, frequently takes place when using a parting tool or a cutting off tool and may be due to one or more reasons: a tendency of the tool or workpiece to spring, the tool is set too high, looseness of the cross-slide, or looseness of the lathe spindle in its bearings.

j. *Taper Turning*.

(1) *General*.

(a) In ordinary straight turning, the cutting tool moves along a line parallel to the axis of the work, causing the finished job to be the same diameter throughout. However, when cutting a taper, the tool moves at an angle to the axis of the work, producing a taper. Therefore, to turn a taper, the work must either be mounted in a lathe so that the axis upon which it turns is at an angle to the axis of the lathe, or cause the cutting tool to move at an angle to the axis of the lathe.

(b) When the diameter of a piece changes uniformly, from one end to the other, the piece is said to be tapered. Taper turning as a machining operation is the gradual reduction in diameter from one part of a cylindrical workpiece to another part (figure 28 on the following page).

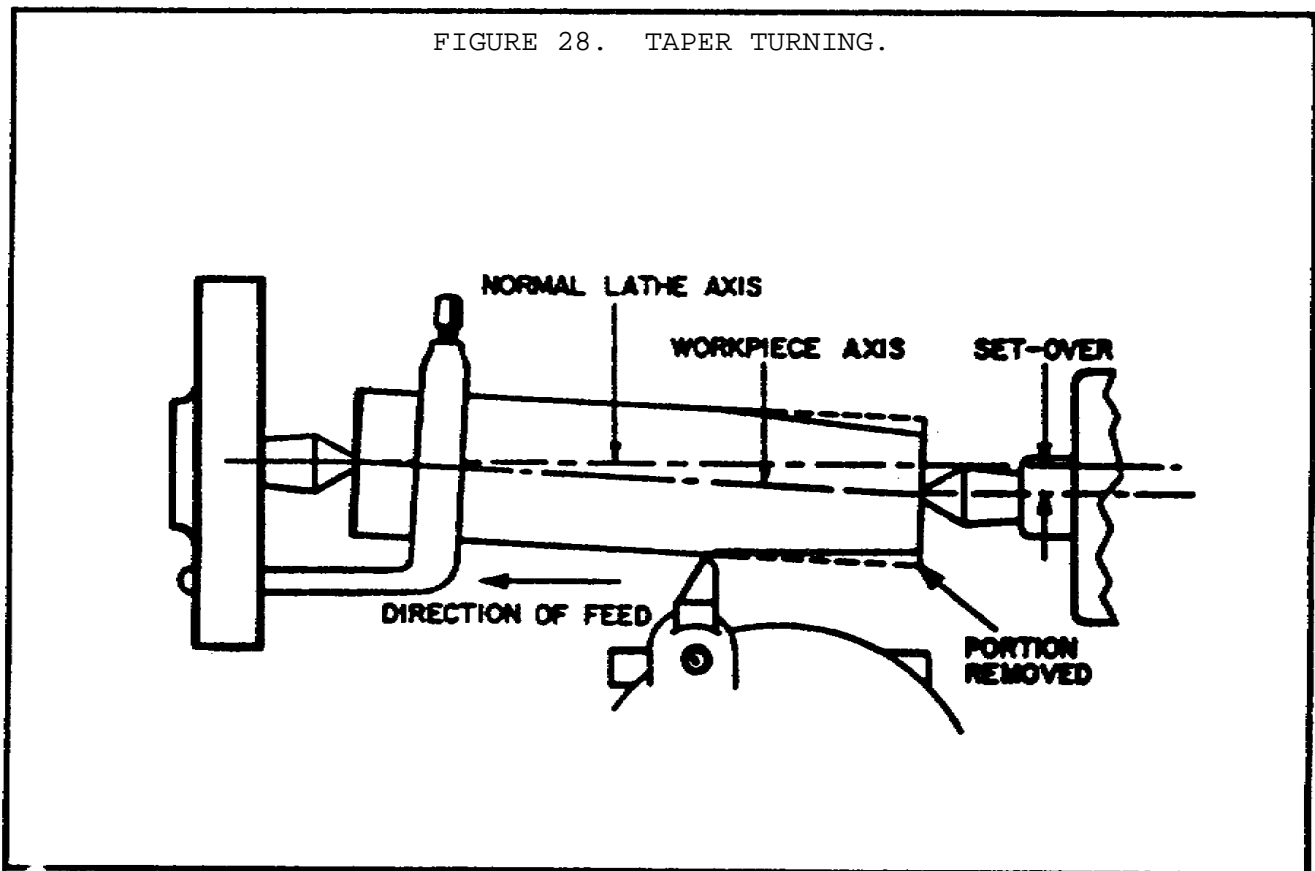
(c) Tapers can be either external or internal. If a workpiece is tapered on the outside, it has an external taper; if it is tapered on the inside, it has an internal taper.

(d) The method used for turning a taper depends on the degree, length, location of the taper (internal or external), and the number of pieces to be done. The three basic methods of turning a taper require the operator to use either a compound rest, offset the tailstock, or use the taper attachment. With any of these methods, the cutting tool must be set exactly on center with the axis of the workpiece or the workpiece will not be truly conical, and the rate of taper will vary with each cut.

NOTE

During this lesson, only two of the taper turning operations will be discussed.

FIGURE 28. TAPER TURNING.



(2) *Compound Rest.*

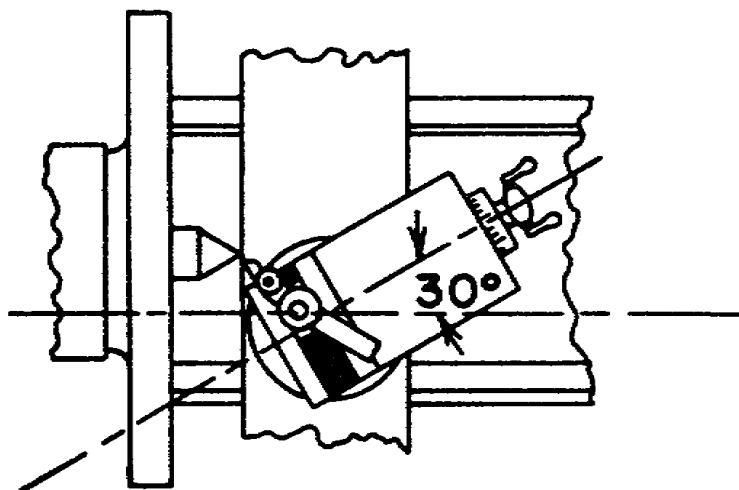
(a) The compound rest is generally used for turning or boring short steep tapers, but it can also be used for longer, gradual tapers, providing the length of the taper does not exceed the

distance the compound rest will move upon its slide. This method can be used with a high degree of accuracy, but is somewhat limited due to the lack of an automatic feed and the length of the taper being restricted to the movement of the slide.

(b) The compound rest base is graduated in degrees and can be set at the required angle for taper turning or boring.

(c) With this method, it is necessary to know the included angle of the taper to be machined. (An included angle is formed by and between two intersecting straight lines.) The angle of the taper with the centerline is one-half the included angle and will be the angle that the compound rest is set for. For example: To true up a lathe center which has an included angle of 60° , the compound rest would be set at 30° from parallel to the ways (figure 29) If the taper is given in taper inches per foot, the angle for the compound rest setting will have to be computed or taken from an appropriate taper sizes and angles table. The formula for computing the compound rest setting is given in two parts:

FIGURE 29. TAPER TURNING USING THE COMPOUND REST.



$$tpi = \frac{ld-sd}{lt}$$

where, tpi = taper per inch
 ld = large diameter
 sd = small diameter
 lt = length of taper
 and

$$\tan L = \frac{tpi}{2}$$

where, tan L = tangent of angle

tpi = taper per inch

For example, the compound rest setting for the workpiece would be calculated in the following manner:

$$tpi = \frac{ld-sd}{lt}$$

$$tpi = \frac{1.000-0.375}{0.750}$$

$$tpi = \frac{0.625}{0.750}$$

$$tpi = 0.833$$

Apply the taper per inch (tpi) received with the formula, to the tangent of the angle formula.

$$\tan L = \frac{tpi}{2}$$

$$\tan L = \frac{0.833}{2}$$

$$\tan L = 0.41650$$

The answer computed with this formula must be worked out to five places to the right of the decimal point. The number is converted to degrees and minutes by reference of the tangent trigonometric tables in FM 43-3 or the American Machinists Handbook.

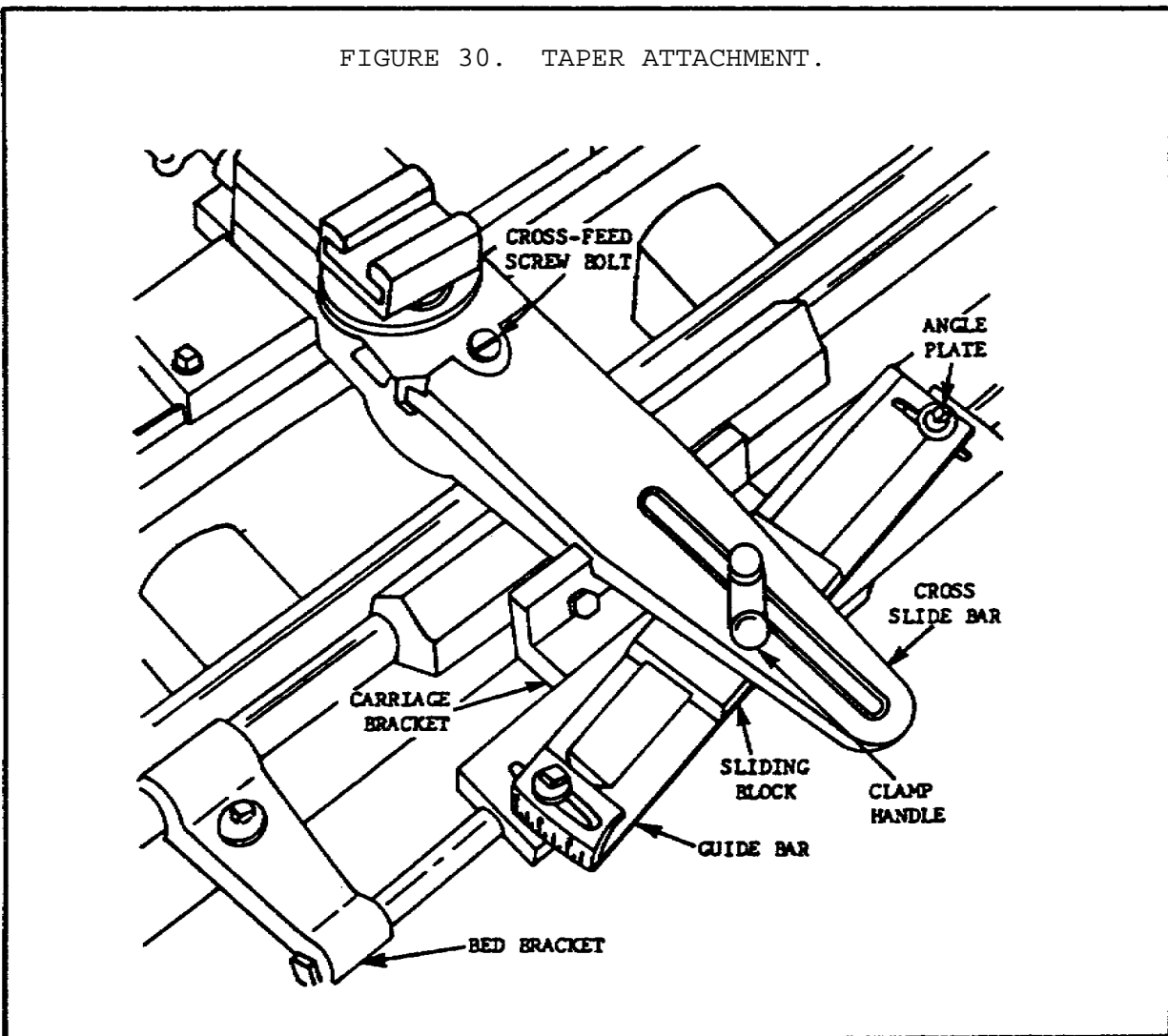
$$\tan L = 0.41650$$

$$\tan L = 22^{\circ}37'$$

(3) *Taper Attachment.*

(a) The taper attachment (figure 30) has many features of special value, among which are the following:

1 The lathe centers remain in alignment and the center holes in the work are not distorted.



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2 The length of the work need not be considered because once the taper attachment has been set, that particular taper will be turned on any piece of any length.

3 The alignment of the lathe need not be disturbed, thus saving considerable time and effort.

4 Taper boring can be accomplished as easily as taper turning.

5 A much wider range is possible than by the offset method. For example, to machine a 3/4 inch per foot taper on the end of bar 4 feet long would require an offset of 1 1/2 inches, which is beyond the capabilities of a regular lathe but can be accomplished by the use of the taper attachment.

(b) Some engine lathes are equipped with a taper attachment as standard equipment and most lathe manufacturers have a taper attachment available. Taper turning with a taper attachment, although generally limited to a taper of 3 inches per foot and to set the length of 12 to 24 inches, affords the most accurate means for turning or boring tapers. The taper can be set directly on the taper attachment either in inches per foot, or (on some attachments) in degrees.

(c) Ordinarily when the lathe centers are in line, the work is turned straight, because as the carriage feeds along, the tool is always the same distance from the centerline. The purpose of the taper attachment is to make it possible to keep the lathe centers in line, by freeing the cross-slide and then guiding it (and the tool bit) gradually away from the centerline (figure 31, view A, on page 72). Also, by guiding it gradually nearer the centerline (figure 31, view B), a taper hole can be bored.

(d) A typical taper attachment for the lathe is illustrated in figure 31. A bed bracket is attached to the lathe bed and keeps the angle plate from moving to the left or to the right. The carriage bracket moves along the underside of the angle plate in a dovetail and keeps the angle plate from moving in or out on the bed bracket. The taper to be cut is set by placing the guide bar, which clamps to the angle plate, at an angle to the ways of the lathe bed. Graduations on one or

both ends of the guide bar are used to make this adjustment. A sliding block which rides on a dovetail on the upper surface of the guide bar is secured during the machining operation to the cross-slide bar of the carriage, with the crossfeed screw of the carriage disconnected. Therefore, as the carriage is traversed during the feeding operation, the cross-slide bar follows the guide bar, moving at the predetermined angle from the ways of the bed to cut the taper. It is not necessary to remove the taper attachment when straight turning is desired; the guide bar can be set parallel to the ways, or the clamp handle can be released permitting the sliding block to move without affecting the cross-slide bar. The crossfeed screw can be re-engaged to permit power to the crossfeed and control on the cross-slide from the apron of the carriage.

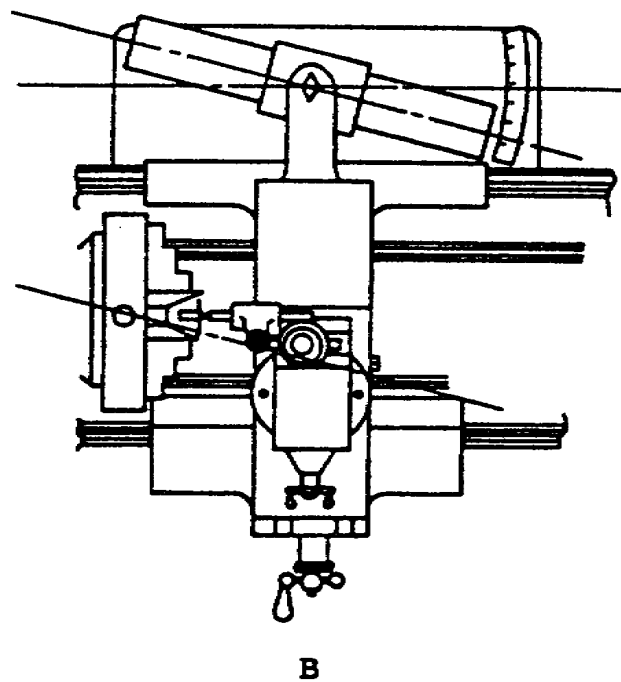
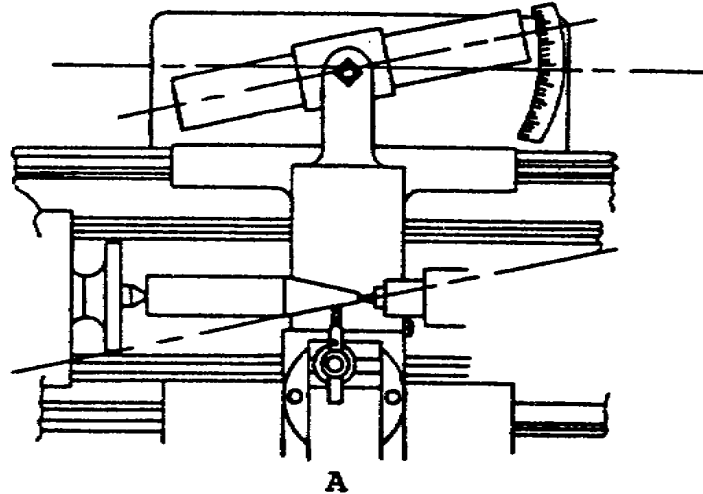
(e) A telescope taper attachment is similar to the plain attachment (which was discussed in the preceding paragraph) except that it is equipped with a telescopic crossfeed screw which eliminates the necessity of disconnecting the crossfeed screw.

To use the telescopic attachment, first set the tool bit for the required diameter of the work and engage the attachment by tightening the binding screws. The location and the number of binding screws depends upon the design of the attachment. The purpose of the binding screws is to bind the cross-slide so that it may be moved only by turning the crossfeed handle or, when loosened, to free the cross-slide for use with the taper attachment. To change back to straight turning with the telescopic attachment, it is necessary only to loosen the binding screws.

(f) When cutting a taper using the taper attachment, the direction of feed should be from the intended small diameter toward the intended large diameter. Cutting in this manner, the depth of cut will decrease as the tool bit passes along the workpiece surface, assisting the operator in preventing possible damage to the tool bit, workpiece, or lathe by forcing too deep a cut.

(g) The length of taper the guide bar will allow is usually not over 12 to 24 inches, depending on the size of the lathe. It is possible to machine a taper longer than the guide bar allows by moving the attachment after a portion of the desired taper

FIGURE 31. SETUP FOR TURNING AND BORING TAPERS.



length has been machined; then the remainder of the taper can be cut.

(h) The depth of cut is obtained by placing the compound rest 90° from parallel with the ways and feeding toward the workpiece with the compound rest

handle. The depth of cut can be gauged with the use of the micrometer collar located on the compound rest.

(i) When using the taper attachment, there is a certain amount of "lost motion" (backlash) which must be eliminated or serious problems will result. In every slide and every freely revolving screw there is a certain amount of lost motion which is very noticeable if the parts are worn. Care must be taken to remove the lost motion before proceeding to cut or the piece will be turned or bored straight for a short distance before the taper attachment begins to work. To take up lost motion when turning tapers, run the carriage back toward the deadcenter as far as possible, then feed it forward by hand to the end of the workpiece where the power feed is engaged to finish the cut. This procedure must be repeated for every cut.

(j) The best way to bore a taper with a lathe is to use the taper attachment. Extreme care must be exercised that the lost motion, or backlash, is removed when tapers are being bored with the taper attachment, otherwise the hole will be bored straight for a distance before the taper starts. Since the power feed can be used with this method it is preferable to using the hand-fed compound rest method. Two important factors to take into consideration are: the boring tool must be set exactly on center with the workpiece axis; and it must be small enough in size to pass through the hole without rubbing at the small diameter. A violation of either of these factors will result in a poorly formed, inaccurate taper, or damage to the tool and workpiece.

(4) *Checking Tapers for Accuracy.*

(a) While the taper is being turned, it is a good practice to stop the lathe after a complete cut of the taper has been made and measure the diameters at each end to determine if the taper is being cut to the required dimensions. An error in calculation must be discovered early because it may be too late for corrective measures after the workpiece is completely rough turned. Also, lay a straightedge along one side of the taper to assure that the taper is uniform. Lack of uniformity can be caused by lost motion in the taper attachment or by play in the compound rest, if the compound rest method is being used.

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(b) A bored taper may be checked with a plug gage by marking the gage with chalk or Prussian blue pigment. Insert the gage into the taper and turn it one complete revolution. If the marking on the gage has been rubbed evenly, the angle of the taper is correct. The angle of the taper must be increased when there is not enough contact at the small end of the plug gage, and it must be decreased when there is not enough contact at the large end of the gage. After the correct taper has been obtained but the gage does not enter the workpiece enough, additional cuts must be taken to increase the diameter of the bore.

(c) An external taper may be checked with a ring gage. This is achieved by the same method as for checking internal tapers, except that the workpiece will be marked with chalk or Prussian blue pigment rather than the gage. Also, the angle of the taper must be decreased when there is not enough contact at the small end of the ring gage and it must be increased when there is not enough contact at the large end of the gage. If no gage is available, the workpiece should be tested in the hole it is to fit. When even contact has been made throughout the workpiece, but the tapered portion does not enter the gage or hole far enough, the diameter of the piece is too large and must be decreased by additional depth of cut.

(d) The taper per inch of any external taper may be obtained by dividing the difference in diameters by the length of the taper in inches measured along the axis of the workpiece between these diameters. For example, to find the taper of a workpiece, or to check whether a taper is being turned correctly, the following method may be used with a pencil or a scribe, draw two lines on the surface of the taper parallel with the ends and, if convenient, a whole number of inches apart. Measure the diameters at these lines and divide their difference by the number of inches between them, the result will be taper per inch. The formula to use when computing taper per inch (tpi) is the same as the one given in paragraph 6j(2)(c), pages 67, 68 and 69.

(5) *Standard Tapers.*

(a) There are various standard tapers in commercial use, the most common ones being: The Morse tapers, the Brown and Sharpe tapers, the

American Standard Machine tapers, the Jarno tapers, and the Standard taper pins.

1 Morse tapers are used on a variety of tool shanks, and exclusively on the shanks of twist drills. The taper for different numbers of Morse tapers is slightly different, but is approximately 5/8 inch per foot in most cases.

2 Brown and Sharpe tapers are used for taper shanks on tools such as end mills and reamers, the taper being approximately 1/2 inch per foot for all sizes except for taper No. 10, where the taper is 0.5161 inch per foot.

3 The American Standard Machine tapers are composed of a self-holding series and a steep taper series. The self-holding taper series consists of 22 sizes. The name "self-holding" has been applied where the angle of the taper is only 2° or 3° and the shank of the tool is so firmly seated in its socket that there is considerable frictional resistance to any force tending to turn or rotate the tool in the holder. The self-holding tapers are composed of the selected tapers from the Morse, the Brown and Sharpe, and the 3/4 inch per foot Machine taper series. The smaller sizes of the self-holding tapered shanks are provided with a tang to drive the cutting tool. Larger sizes employ a tang drive with the shank held with a draw bolt. The steep machine tapers consist of a preferred series and an intermediate series. A steep taper is defined as a taper having an angle sufficiently large to insure the easy or self-releasing feature. Steep tapers have a 3 1/2 inch taper per foot and are used mainly for aligning the milling machine arbors and spindles, and on some lathe spindles and their accessories.

4 The Jarno taper was originally proposed by Oscar J. Beale of the Brown and Sharpe Mfg. Co. This taper is based on such simple formulas that practically no calculations are required when the number of taper is known. The taper per foot for all Jarno tapers is 0.600 inch per foot. The diameter at the large end is as many eighths, the diameter at the small end is as many tenths, and the length as many half-inches as indicated by the number of the taper. For example: A No. 7 Jarno taper is 7/8 inch in diameter at the large end; 7/10

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or 0.7 inch in diameter at the small end; and 7/2 or 3 1/2 inches long. Therefore, formulas for these dimensions would read:

$$\text{Diameter at small end} = \frac{\text{No. of taper}}{8}$$

$$\text{Diameter at small end} = \frac{\text{No. of taper}}{10}$$

$$\text{Length of taper} = \frac{\text{No. of taper}}{2}$$

The Jarno taper is used on various machine tools, especially profiling machines and for die-sinking machines. It has also been used for the headstock and tailstock spindles on some lathes.

5 The Standard taper pins are used for positioning and holding parts together and have a 1/4 inch taper per foot. Standard sizes in these pins range from No. 7/0 to No. 10. The tapered holes used in conjunction with the tapered pins use the processes of step-drilling and taper reaming.

(b) To preserve the accuracy and efficiency of tapers (shanks and holes) they must be kept free from dirt, chips, nicks, or burrs. The most important factor in regard to tapers is to keep them clean. The next most important factor is to remove all oil by wiping the tapered surfaces with a soft, dry cloth before use, because an oily taper will not hold.

7. Conclusion

During this task, we have discussed the various types of lathes, accessories, uses, and some of the lathe operations that the machinist will encounter in the machine shop. With proper application, this information will assist those dealing with lathe operations or the machinists that are performing these functions in the metalworking field. In task two and three of this lesson, grinding, milling attachments, and thread forms will be discussed.

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 2

LESSON 1

THE LATHE USES AND SAFETY; USES, REPAIR, AND
ADJUSTMENT OF LATHE ATTACHMENTS; AND VARIOUS
THREAD FORMS, USES, CALCULATIONS, AND
MACHINING TECHNIQUES

TASK 2. Describe the uses, repair, and adjustment of lathe attachments.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within one hour

REFERENCES

No supplementary references are needed for this task.

1. Introduction

When manufacturing or rebuilding components to replace worn ones in the field, the machinists, at times, is limited to the type of operations he can perform because the type of machines needed are not available in his particular shop set or van. Therefore, manufacturers have developed various attachments that can be mounted on the lathe to bridge this gap. These attachments, when mounted on the basic engine lathe, will allow the machinists to perform milling, grinding, drilling, and slotting operations. During this task, we will discuss the uses, repair, and adjustments on some of the lathe attachments.

2. Toolpost Grinder

a. *General.* The toolpost grinder (figure 23 on page 44) is a portable grinding machine that can be mounted on the compound rest of the lathe in place of the toolpost. It can be used to machine work

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that is too hard to cut by ordinary means or to machine work that requires a very fine finish. It is known as either a toolpost grinding machine or a toolpost grinder.

b. *Uses.* The toolpost grinding machine is a machine tool attachment specially designed for cylindrical grinding operations on the lathe. It consists primarily of a 1/4 or 1/3 horsepower electric motor and a wheel spindle connected by means of pulleys and a belt. The machine fastens to the compound rest of the lathe with a T-slot bolt which fits into the T-slot of the compound rest in the same manner as the lathe toolpost.

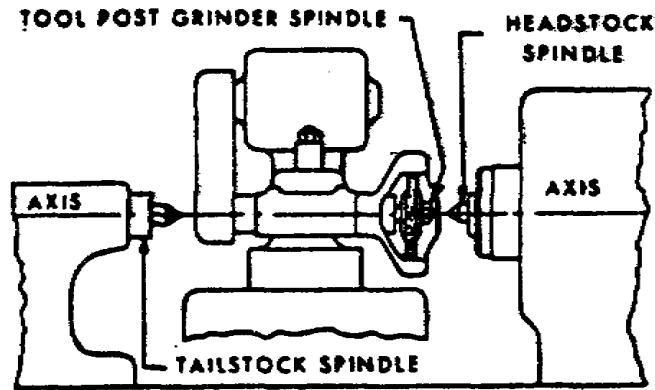
The toolpost grinding machine mounts grinding abrasive wheels ranging from 1/4 to 3 or 4 inches in diameter for internal and external grinding operations. The pulleys on the wheel spindle and motor shaft are interchangeable to provide proper cutting speeds for the various wheel sizes. The larger grinding abrasive wheels used for external grinding are attached to the wheel spindle with an arbor. Small grinding wheels used for internal grinding are fixed in a chuck which screws onto the wheel spindle. The electric motor is connected to an electrical power source by means of a cable and a plug. A switch is usually provided at the attachment to make it easier to start and stop the motor.

c. *Operation.*

(1) The toolpost grinder and grinding wheel takes the place of a lathe cutting tool, in that it can perform most of the same operations as a cutting tool. Cylindrical, tapered, and internal surfaces can be ground with the toolpost grinder. Very small grinding wheels are mounted on tapered shafts, known as quills, to grind internal surfaces. All toolpost grinding must be performed with the grinding spindle center adjusted to the exact height of the work center (figure 32 on the following page).

(2) The grinding wheel speed is changed by using various sizes of pulleys on the motor and spindle shafts. An instruction plate on the grinder gives both the diameter of the pulleys required to obtain a given speed and the maximum safe speed for grinding wheels of various diameters. Grinding wheels are safe for operation at a speed just below

FIGURE 32. MOUNTING THE GRINDER AT THE CENTER HEIGHT.



the highest recommended speed. A higher than recommended speed may cause the wheel to disintegrate. For this reason, wheel guards are furnished with the toolpost grinder to protect personnel against injury.

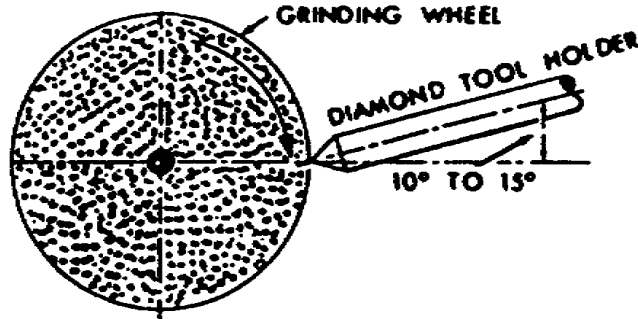
(3) Always check the pulley combination given on the instruction plate of the grinder when a wheel is mounted. Be sure that the combination is not reversed, as this may cause the wheel to run at a speed far in excess of that recommended. During all grinding operations, wear goggles to protect your eyes from flying abrasive material.

(4) The grinding wheel must be dressed and trued. Use a diamond wheel dresser to dress and true the wheel. The dresser is held in a holder that is clamped to the chuck or faceplate of the lathe. The point of the diamond is to be set at center height and at a 10° to 15° angle in the direction of the grinding wheel rotation, as shown in figure 33 on the following page. The 10° to 15° angle prevents the diamond from gouging the wheel. The lathe spindle is locked by placing the spindle speed control lever in the low rpm position.

NOTE

The lathe spindle does not revolve when the grinding wheel is being dressed.

FIGURE 33. POSITION OF THE DIAMOND DRESSER.



(5) When truing a grinding wheel, bring the center of the wheel face in contact with the diamond by carefully feeding the cross-slide in by hand. Move the wheel clear of the diamond and make a cut by means of the cross-slide. The maximum depth of cut is 0.002 inch. Move the wheel slowly back and forth over the point of the diamond. Move the carriage if the face of the wheel is parallel to the ways of the lathe. Move the compound rest if the face of the wheel is at an angle. Make the final depth of cut of 0.0001 inch with a slow even feed to obtain a good wheel finish. Remove the diamond dresser as soon as the wheel is dressed properly. Adjust the grinder to begin the grinding operation.

(6) Rotate the work at a fairly low speed during the grinding operation. The recommended surface foot speed is 60 to 100 feet per minute (fpm). The depth of cut depends upon the hardness of the workpiece, the type of grinding wheel, and the desired finish. Avoid taking grinding cuts deeper than 0.002 inch until experience is gained. Use a fairly low rate of feed. Experience will soon allow one to be able to judge whether the feed is to be increased or decreased. Never stop the workpiece or the grinding wheel while they are in contact with each other.

d. *Selecting the Proper Quill.* Accuracy, quality of finish, and metal removal rate depend upon the selection of the correct quill for a specific grinding job. Complete dimensions and specifications of all Dumore quills appear in the TM 9-3460-215-10. The correct quill should be

selected for the grinding job by dimension and type as given in the appropriate table. Two or more quills in a model series may meet the same dimensional requirements of a specific grinding operation or application. Always choose the quill with the greatest rigidity for greater accuracy, finer finish, and longer wheel life. For internal grinding, select a three-bearing quill whenever possible. If job size limits the selection of two-bearing insert type quills, select the insert spindle with the shortest practical extension. For all types of grinding, choose the quill that offers the largest possible wheel diameter. Larger wheels operate at lower speeds, run cooler, last longer, and provide greater accuracy and finer finishes.

e. *Maintenance.*

(1) *Lubrication.* The motor requires no lubrication since it is equipped with grease sealed ball bearings.

(2) *Quills.*

(a) Some Dumore quills are equipped with ball bearings packed with grease in assembly. These require no lubrication. They can be operated in any position. Other quills are made with "fog of oil" lubricating system, and are identified by the plug marked "OIL." Before these quills are put into use, and also after being stored for a long period of time, 180 drops of spindle oil should be added. Oil quills regularly but not to excess, as too much oil causes the quills to overheat. Do not allow dirt to enter into the quills when adding oil.

(b) All Dumore quills are equipped with water and dust throwers. When used for wet grinding, always start the spindle rotating before the coolant is turned on; and turn the coolant off before stopping the spindle. Never allow the coolant to flow on the quill when the spindle is not rotating.

(3) *Brushes.*

(a) Normal brush life varies from 500 to 2000 hours depending upon the severity and continuity of service. Brushes should be inspected periodically and wiped clean before returning them to their

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 2

respective brush holders if they are long enough for additional use. Each brush should be returned to its exact position as before removal to prevent changes in the brush seating. Brushes should be replaced when worn to 1/4 inch in length.

(b) Whenever brushes are replaced, the commutator should be turned down and undercut. New brushes on a badly worn commutator will spark excessively, giving very little life.

3. Metal Cutting Lathe Fixture

a. *General.*

(1) The metal cutting lathe fixture is a work holding device which mounts on the compound of a conventional lathe (figure 34 on the following page). Machining is accomplished with the cutter held in the chuck or collet of the lathe spindle. The fixture provides vertical travel which is used with the longitudinal and traverse of the lathe. Power feed and a wide range of spindle speeds are already built into the lathe.

(2) Capacities of the fixture are 2 inch diameter round stock and up to 2 inch square in flat stock. The length of stock is unlimited.

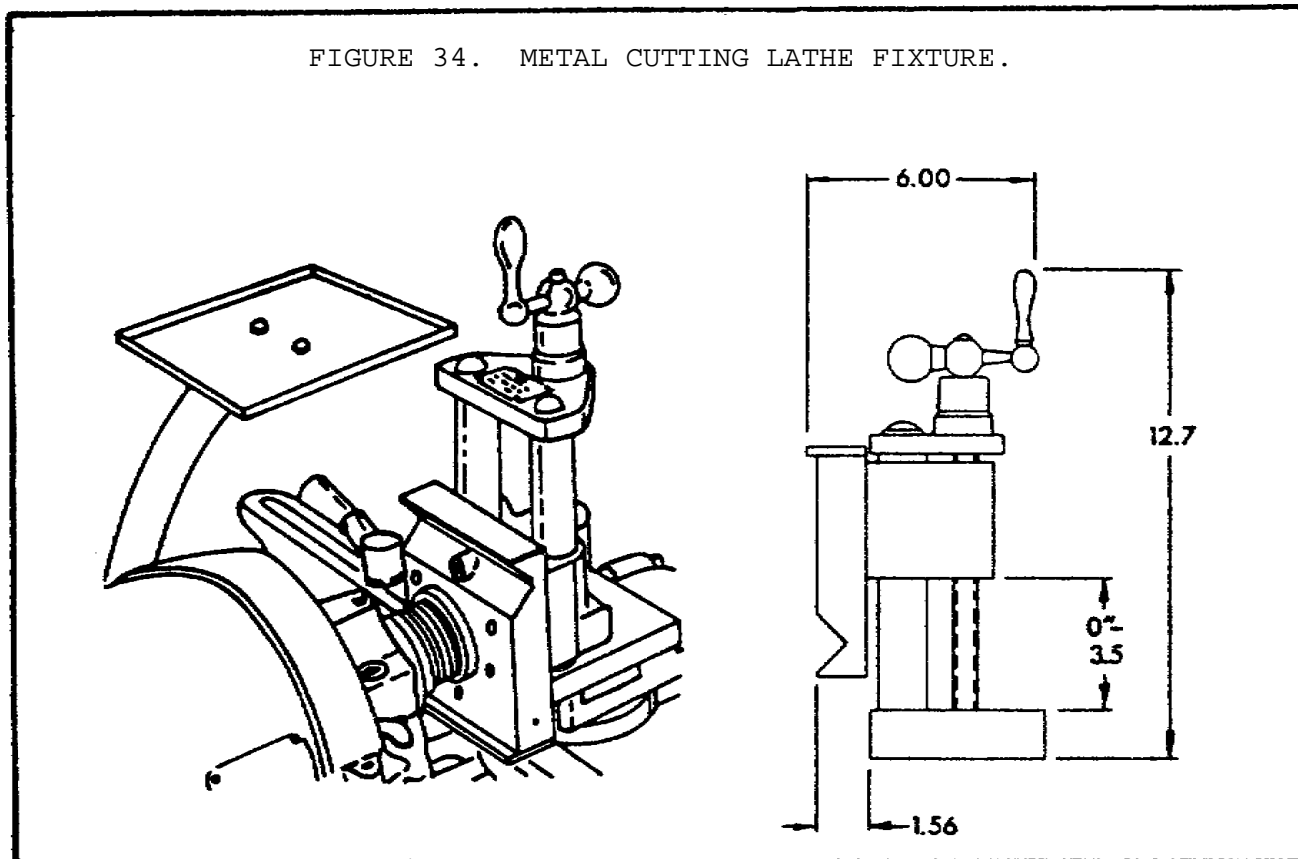
b. *Installation.*

(1) *General.* The metal cutting lathe fixture is a precision tool. It can not be more accurate than the lathe on which it is being used. Before mounting the fixture, check the lathe compound. Remove any burrs or surface irregularities with a file and check the top of the compound for trueness in both directions of travel. Compounds on most lathes are true to within .001 inch in either direction, and this is acceptable for use with the fixture. Mount the fixture on the lathe following these procedural steps:

Step 1. Slide the fixture onto the compound with the T-slot mounting clamp in the T-slot of the compound and lightly tighten the mounting screws.

Step 2. Bring the fixture plate into full contact with the lathe faceplate or face of the lathe spindle as shown in figure 34 to align the fixture laterally. This provides adequate alignment for

FIGURE 34. METAL CUTTING LATHE FIXTURE.



most machine operations. Where extreme accuracy is required, align the fixture laterally with a dial indicator.

Step 3. Make certain that the fixture plate is horizontally aligned with the cross travel of the lathe. Horizontal alignment, adequate for most operations, can be achieved by loosening the two fixture plate screws and positioning the vertical edge of the fixture plate parallel with the side of main housing. On operations calling for tolerances closer than .001 inch, align the flange of the fixture plate with a dial indicator.

(2) The fixture is now aligned and ready to perform various machining operations. The fixture can be rotated about a vertical axis to any angle by means of the lathe compound without disturbing the vertical alignment.

c. Operation.

(1) *General.* The same safety precautions should be observed when machining with this fixture as with any tool. Always wear safety glasses for eye

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protection. Loose clothing and neckties should never be worn when machining.

(a) When round stock is to be machined, assemble the fixture plate to the main body housing keeping the V-groove down. Secure the workpiece with the stock clamps, using the jack screws to level the stock clamps. Select the length required from the assortment of screws furnished.

(b) When machining large diameter stock, assemble the jack screws in the stock clamps with the screw heads against the fixture plate.

(c) When machining flat stock, assemble the fixture plate to the main body housing keeping the V-groove up. Set the workpiece on the fixture plate flange and clamp the workpiece in the same manner as for round stock.

NOTE

Whenever the fixture plate is repositioned, it must be realigned as previously described in step 3, paragraph 3b on page 83.

(d) The lead screw will accurately position the workpiece by moving the main body housing along the guide posts. The lead screw has 10 threads per inch, and the lead screw graduated collar is calibrated to .001 inch. For direct reading, turn the lead screw graduated collar to zero by loosening the collar set screw.

(2) *Milling.* Milling operations are performed with the workpiece clamped to the fixture, and the milling cutter held in the lathe chuck or collet. The workpiece may be hand fed in any direction; lathe power feeds may be used for longitudinal or traverse travel.

(3) *Boring.* The rigidity of the fixture assures accurate boring. The boring head is mounted in the lathe spindle. The workpiece is predrilled and mounted in the fixture. The machine is then turned on and the workpiece fed into the boring head, this operation is continued until the proper size is achieved.

(4) *Layout.* Holes can be laid out using the cross feed of the lathe and the vertical fed of the fixture. Use the compound feed to control the depth and for locating the angular holes.

(5) *Indexing.*

(a) The workpiece is accurately indexed by use of the large graduated collar. The method of centering the workpiece is as follows:

Step 1. Visually center the workpiece in the graduated collar and lightly tighten the 3 set screws against the workpiece.

Step 2. Using a micrometer, measure across all three set screws (figure 35 on the following page). Total the 3 readings and divide them by 3.

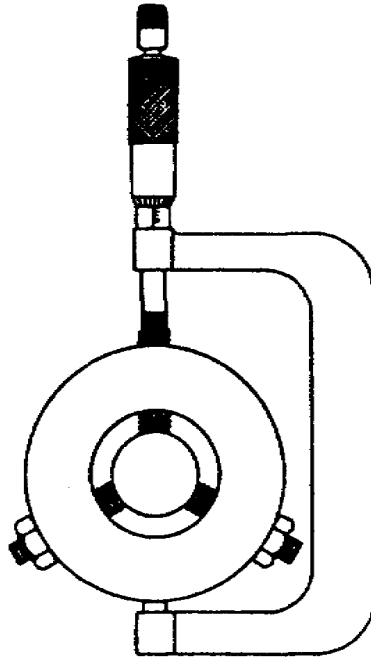
Step 3. Loosen the top set screw and adjust the other two set screws to the dimension outlined in step 2. Lock these two set screws with jamnuts. Tighten the top set screw against the workpiece. Recheck all three settings with the micrometer.

Example: Using .751 diameter stock and with readings of 3.058, 3.085, and 3.071 totaling 9.214, and divide this reading by 3. The reading should be 3.071. The three set screws should be adjusted to the 3.071 dimension.

(b) When machining a quantity of like parts having exactly the same diameter, two of the set screws can be kept securely tightened with the jam nuts after centering the graduated collar for the first machined part. After machining, the graduated collar is removed by loosening the screw which does not have a locknut. The collar can then be used for machining the remaining parts without having to measure the concentricity each time.

(6) *Internal Keyway Cutting.* Internal keyways are cut with the same type of set-up as used for boring. The fixture is mounted on the lathe compound, with the fixture plate parallel to the lathe bed. Mount the boring bar in the V-groove keeping the tool slot of the boring bar in a vertical position, so that the cutter may be brought up to the top position of the workpiece bore. Use the lathe cross-slide to center the

FIGURE 35. CENTERING THE WORKPIECE USING A MICROMETER.



cutter with the top of the bore on the workpiece. Feed upward with the workpiece and complete the cutting of the keyway in a series of draw cuts, keeping the lathe spindle motionless.

d. *Maintenance.*

(1) *Lead Screw Backlash.*

(a) If backlash develops in the lead screw, it is removed either by eliminating the end play in the top cap, or by adjusting the fit-up of the lead screw bushing.

(b) Inside the graduated collar is a threaded retainer collar. This threaded collar governs the tightness or preload on the lead screw thrust bearings. Removing the end play between the top cap and the lead screw is accomplished by tightening the threaded retainer collar until a slight binding is felt, and then locking the threaded collar with the set screw.

(c) End play between the lead screw and the main body housing is controlled by the lead screw bushings. The lower bushing is the one normally adjusted by turning it to the left after releasing the set screw. Continue turning the bushing until a slight binding begins, then lock it in position.

(d) If the lead screw bushing threads have become worn, adjustment of the bushing is made by turning it to the right so that the opposite sides of the thread are brought to use.

(2) *Lubrication.* The lead screw and the guide posts are lubricated through grease fittings on the main body housing. When the fixture is not in use, protect all unpainted parts with a light film of oil.

4. Milling, Grinding, Drilling, and Slotting Attachment (Versa-Mil)

a. Basic Unit.

(1) *General.*

(a) Various operations can be performed on the lathe, milling machine, shaper, planer, and other type of machines with the use of a milling, grinding, drilling, and slotting attachment which is referred to as the Versa-Mil (figures 24 and 36 on page 46 and 89 respectively.)

(b) The versa-mil is a precision tool that consists of a motor driven Basic Unit plus auxiliary heads and accessories. It may be combined with machine tools by mounting it in any position on the carriage, table, ram, turret, or tool arm.

(c) The complete versa-mil equips all machine shops for any milling, drilling and boring, grinding, keyseating, slotting or shaping problems that may be encountered. The basic unit alone adds many new operations to standard machine tools. The interchangeable precision heads and other units may be added to equip a shop for any particular or specific operations required.

(2) Milling operations may be performed on the lathe through the use of the milling and grinding attachment which, in effect, converts the lathe into a milling machine (versa-mil). The versa-mil

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contains a mechanism for vertical adjustment of the milling head but utilizes the carriage and feed controls of the lathe to move the milling head in the horizontal direction. An indexing head is supplied with the versa-mil and is installed on the headstock spindle of the lathe to permit indexing the workpiece. Although the workpiece is mounted in a conventional manner in the lathe, the headstock spindle is never rotated by power for milling functions (figure 36 on the following page). Cutting is done by the milling head of the versa-mil and is driven by the self-contained motor of the attachment.

b. *Mounting of the Versa-Mil.*

(1) *General.* The versa-mil is rigidly constructed and is designed to take heavy cuts without chatter. However, no tool can be more rigid than the base on which it is mounted. Care should be taken to ensure that the carriage, compound rest, ram or tool arm on which the versa-mil is mounted is solid, and that the mounting bolts in the base plate are pulled up tight.

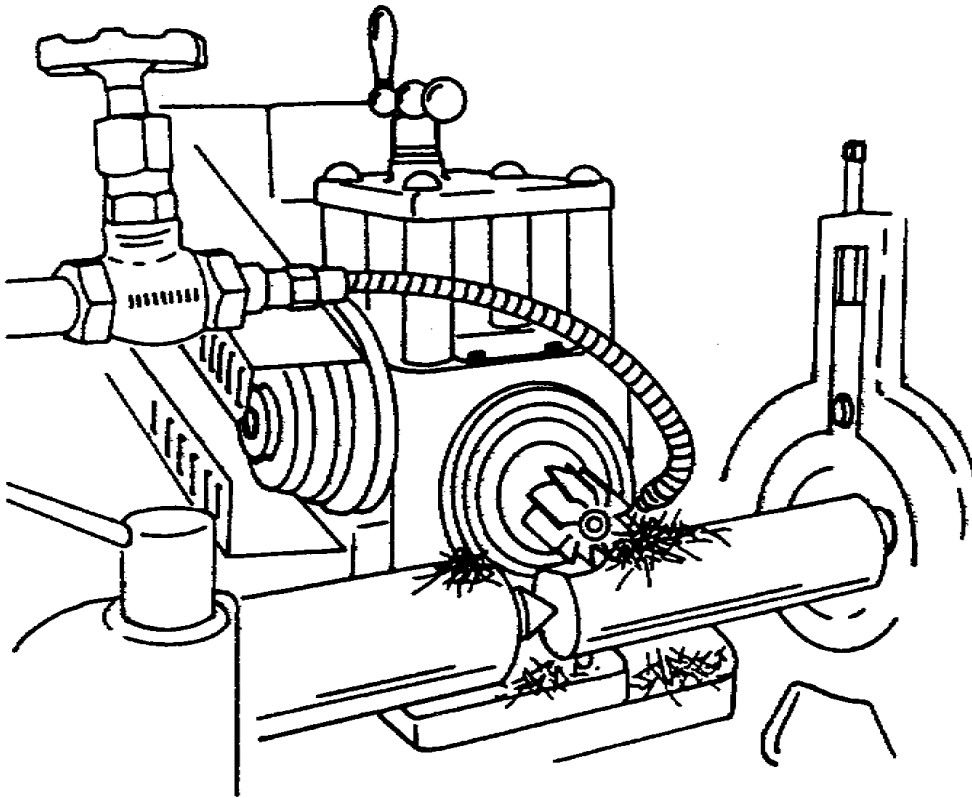
NOTE

The versa-mil can be mounted on the milling machine, shapers, planers, boring mills, and various other types of machine tools. However, for this task, only those areas concerning mounting the versa-mil on the lathe will be covered.

(a) Gibs should be as snug as possible and still allow the necessary movement. Those gibs governing movements not necessary for the operation being done should be tight to prevent movement and chatter.

(b) It is important that the workpiece be solidly supported to prevent vibration and chatter. If the workpiece is held between centers, they should be tight against the work. Long pieces should be supported at the point where the work is being done.

FIGURE 36. MILLING OPERATIONS ON THE LATHE.



NOTE

Unless both versa-mil and the work are rigidly supported, it is difficult to obtain accurate, chatter-free results.

(c) The bases of the basic unit are provided with two sets of mounting holes. Two cap screws in the opposite holes are used to attach the base. The alternate holes permit a 90° change in position. Before tightening the cap screws, the circular face plate should be square with the work or the work table surface.

(d) An adapter plate may be necessary for mounting on some machine tools where the center distance of the base plate holes does not conform

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with the mounting surface available. The basic unit may be mounted either vertically or horizontally.

(2) *Mounting on a Lathe.*

(a) The versa-mil is mounted on either the rear or the front of the lathe carriage. On the front, it may be set on the compound or directly on the cross-slide. A more permanent and generally more useful mounting is at the rear of the carriage, where it may be left until it is needed in other areas within the shop. The front lathe mounting has the advantage of requiring very little preparation.

(b) The simplest and the most common mounting is on the compound, in the toolpost position. For this mounting, an adapter bar, to fit into the toolpost T-slot is needed. This is preferably a piece of cold rolled steel, usually 3/8 inch thick and with a width to fit into the T-slot. Two holes are drilled and tapped in the middle of the bar (see appropriate manual for size of threads required). If the versa-mil is to be used on more than one lathe, bars to fit each toolpost T-slot should be made.

NOTE

Hex head cap screws are the easiest to use for mounting bolts. If the bolts strike the bottom of the T-slot before the heads seat on the base plate, cut off enough of the ends to insure rigid mounting.

(c) The toolpost is removed and the adapter bar inserted in the T-slot. The cap screws are used in holes in the opposite sides of the base and inserted in the threaded holes of the adapter bar.

(d) The unit is either mounted in line, or across the compound rest feed, depending on the direction of the back thrust resulting from the work being done. As insurance against movement along the T-slot, it is preferable that the back thrust be across the T-slot.

(e) Mounting on top of the compound rest is usually used for milling on the top surface of the workpiece and when using either of the grinding heads and the hi-speed cutting head, the versa-mil is mounted on the front of the compound rest.

(3) *Mounting on the Lathe Cross-Slide.*

(a) For work requiring that the basic unit be moved down or below the lathe center, it is generally necessary to mount the unit directly to the cross-slide. On most lathes, there is sufficient vertical distance between the top surface of the compound rest and the lathe center to permit the tool in the basic unit spindle to move down to the lathe center.

(b) When a workpiece requires the front surface to be machined on a versa-mil, the compound rest is removed. The two T-bolts, located in the circular T-slots of the compound, are used for mounting the unit. The diameter of the circular slot is generally greater than the center distance of the mounting holes. The T-bolts are moved toward the lathe center until they are spaced to correspond with the side mounting holes. The unit is then placed on the cross-slide with the T-bolts protruding through the mounting holes and secured.

(4) *Mounting on the Rear of the Cross-Slide.*

(a) The most desirable lathe mounting location for the basic unit is at the rear of the cross-slide. Therefore, the basic unit may be left in position (accurately aligned with the lathe) between jobs. Its position at the rear does not interfere with the use of the lathe for turning, and it makes the lathe a combination turning and milling machine. It is able to do complete shaft and spindle jobs in one handling and set up, with considerable savings in job time.

(b) To avoid machining a special adapter to mount the basic unit, an extra lower slide can be procured from the manufacturer.

(c) To install the unit to the rear cross-slide, remove the chip guard from the rear of the cross-slide. Mount the extra "lower slide" on to the rear of the cross-slide ways, back-to-back with the one carrying the compound. Install the extra

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gib and gib screws, adjusting the gib to provide a snug fit on the carriage dovetail.

(d) Make a link from a piece of 1/8 inch steel plate which is the width of the cross-slide. Its length will be determined by the distance between the holes on the two slides which were originally provided for attaching the chip guard. Two holes must be drilled to coincide with the one hole in each of the slides. The two screws originally holding the guard are now used to tie the two slides and the link together (refer to the appropriate manual for further installation procedures).

(e) The rear slide is moved forward with the cross-slide lead screw to determine whether the middle of the circular T-slot (or compound mounting boss) can be brought in line with the lathe spindle center. On the design of some lathes, the cross-slide is too long to permit this procedure because of the amount of lead screw travel. In a case such as this, remove part of the rear slide so that the center of the compound mounting surface may be brought closer together. Re-machine where needed to provide a seat for the link and a hole for the link screw.

(f) Install the extra T-slot bolt into the T-slot and mount the basic unit in position with the faceplate parallel to or at 90° to the lathe axis. Since the gib of the rear slide will normally be kept tighter than the front gib, the rear gib may be released when the versa-mil is not being used.

c. Alignment of the Versa-Mil.

(1) Aligning with the Workpiece.

(a) The circular face plate of the basic unit provides a reference surface for aligning the spindle of the versa-mil with the machine tools to which it is attached, or with the workpiece.

(b) To avoid over-size cuts, the cutter must be aligned with the travel of the carriage, ram, or the cross rail on which it is mounted.

(c) Any pair of the guide posts may be used for referencing since the posts are square with the spindle and the face plate.

(2) *Alignment with the Lathe.*

(a) Before tightening the base of the unit in position, the face should be lined up with the direction of travel. When it is known that the workpiece surface is true with the carriage travel, the versa-mil may be aligned by bringing the basic unit face plate close up to even contact with the workpiece surface.

(b) The tailstock quill also provides a similarly used reference surface.

(c) Another method in aligning the unit with the lathe is to use the lathe face plate or face of the chuck. This is accomplished either by truing the face of the basic unit against the lathe faceplate or chuck, or using a square, parallels or protractor, depending on the setting used.

(d) When the versa-mil is mounted on the compound rest, the compound should be set at zero degrees during alignment to give a direct reading of any angular settings that may be required.

d. *Position of the Spindle.*

(1) The lead screw on the versa-mil will accurately position the spindle by moving the housing along the guide posts. The lead screw is 10 threads per inch; the lead screw collar is calibrated to 0.001 inch.

(2) For direct reading of the depth of cut, the graduated collar may be turned to read zero by turning and loosening the collar set screw.

(3) When the spindle has been brought into position, the housing should be locked to ensure that an accurate depth of cut is maintained. The post lock operates against both front posts. A right-hand turn of the post lock, with a socket key, locks the spindle firmly in position. The lock should be released before operating the lead screw.

e. *Inserting and Removing the Arbors.*

(1) Both spindle taper and arbor tapers are carefully and accurately ground. Care should be taken to avoid the presence of any grit on either surface when inserting the arbors. It is advisable

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to wipe off the arbor with a slightly oiled clean cloth before inserting the arbor into the spindle.

(2) The arbor is drawn into the spindle taper by a draw bar with a right hand thread. The draw bar is operated by the small hex head screw located at the rear of the unit, under the motor mount boss. The draw bar is tightened by placing the socket key at the side of the draw bar wheel to prevent its turning, and then rotating the worm sheave to the rear by hand until the arbor is firmly seated in the spindle.

(3) To remove the arbor, the draw bar wheel is turned to the left, until the arbor is freed from the taper. The arbor may then be turned out by hand. Use the socket key, turning the worm spindle to the front, reversing the procedure for tightening or to release the arbor.

f. *Mounting and Removing Cutters from Arbors.*

(1) Bore type of cutters such as side milling cutters should be mounted on the arbor before the arbor is placed in the spindle, and should be removed only after the arbor has been removed from the spindle.

(2) Particular care should be taken to avoid sharp hammering blows on the arbor or spindle that may be transmitted against the face of the gear teeth and thereby causing damage to their fine precision finish.

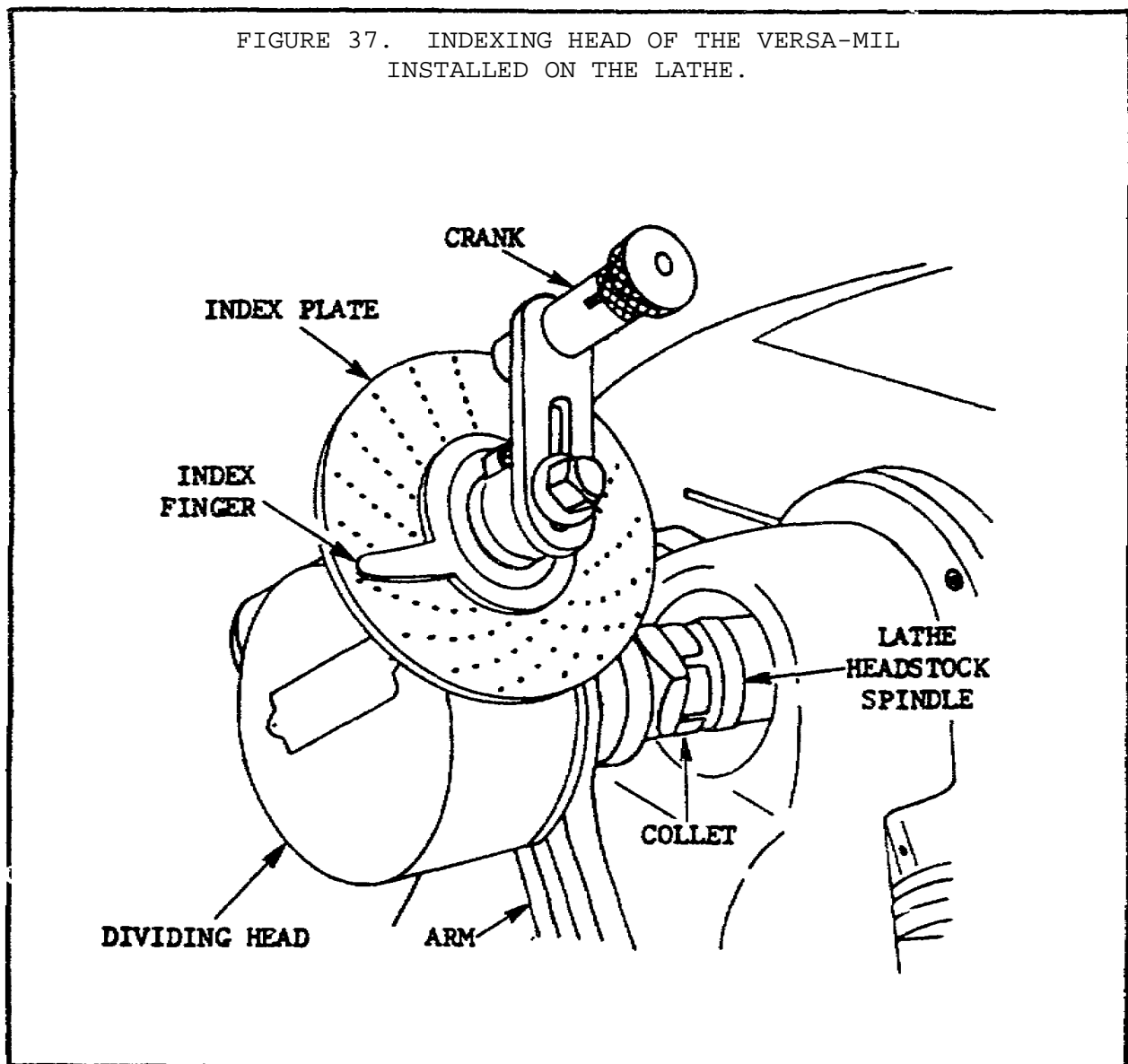
g. *Mounting Workpieces for Milling on the Lathe.* Workpieces are supported in the lathe between centers, against a faceplate, or in a chuck fixed to a headstock spindle. A lathe dog is used to secure the workpiece to the driving faceplate if the workpiece is mounted between centers. If long workpieces are chuck-mounted, a steady rest or a follower rest is used to support the free end of the workpiece.

h. *Indexing Workpieces for Milling on the Lathe.*

(1) Indexing is the process of controlling the rotational position of a workpiece which is mounted axially. Workpieces mounted in the lathe for milling with the milling and grinding lathe attachment (versa-mil) are indexed with the indexing head, a part of the attachment.

(2) The indexing head (figure 37) attaches to the left end of the lathe headstock. The expanding mandrel, with a split-sleeve adapter, is inserted into the lathe spindle for driving or holding the spindle. With the indexing head affixed to the headstock and headstock spindle, the spindle will not rotate freely, but will move when the crank of the indexing head is turned. Forty turns of the crank will move the headstock spindle through one complete revolution. Caution must be taken to insure that the headstock spindle is in a neutral position before the indexing head is attached. Index plates containing concentric rings of evenly spaced holes are fastened to the index head beneath the crank. Each concentric ring has a different number of holes per circle, and each index plate has six concentric rings.

FIGURE 37. INDEXING HEAD OF THE VERSA-MIL
INSTALLED ON THE LATHE.



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(3) The workpiece is indexed by moving the crank from one hole in the index plate to another. An index finger (figure 37 on the previous page) can be set to indicate a certain number of holes thereby making the counting of individual holes unnecessary.

(4) To determine the number of holes and the proper ring of holes for any specific division of the workpiece refer to the appropriate Technical Manual.

i. *Milling Operation.*

(1) Plain milling, angular milling, face milling, form milling, keyway milling, spline milling, gear cutting, and drilling and boring operations can be successfully performed on the lathe by using the milling and grinding lathe attachment.

(2) The basic difference between milling on a horizontal milling machine and milling with the milling and grinding lathe attachment is that with the milling machine the worktable reciprocates beneath a milling cutter; with the attachment, the milling head feeds along the stationary workpiece.

(3) If a coolant attachment is available, flood the milling cutter and workpiece with an appropriate cutting oil. If a coolant attachment is not available, apply cutting oil generously from a hand oiler during the operation.

j. *Lubrication and Adjustments.*

(1) *Lubrication.*

(a) *General.* The internal mechanism of the Basic Unit is enclosed in an oil-tight housing, which contains lubricating oil carefully selected for the requirements of the high performance of the Basic Unit.

(b) After the first three or four weeks of use, the oil should be drained out, the oil reservoir half filled with kerosene, and the basic unit operated without a load for about five minutes. The kerosene should then be removed and clean oil provided. The oil level should be up to the top of the worm, with the basic unit in a vertical position.

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(c) After the initial change, the oil should be changed every three to four months, depending on the amount of use. Cleaning and flushing the oil is important, since the oil is subject to heat and wear the same as the oil of an automobile.

(d) To change the oil, remove the cover plate, which is held on the main casting with eight screws.

(e) For general use, the basic unit should be filled with oil up to the top of the worm to ensure that the worm and the gear will be lubricated in all operating positions. In production installations where the main spindle will remain horizontal, the oil may be reduced to 1 inch in depth, which will give an even cooler operation on continuous runs.

(f) Ordinary cylinder oils may not provide the film necessary to properly protect the fine precision finish of the worm and gear. Use ONLY Gargoyle Oil, Almo #5 or its nearest equivalent available. In military installations, the first choice should be oil conforming to specification: MIL-L-15019A-type #4065. Second, use Federal Specification #VV-L-765 SAE 80 or 90.

(g) A light film of oil should be kept on the posts to preserve their finish. This will be sufficient lubrication for the post sleeves. The lead screw and the lead screw collar should be occasionally lubricated with a good grade of machine oil.

(h) The motor bearings have been packed with high grade ball bearing grease sufficient for about two years of average operation. To regrease, remove the set screws from each hub and insert a good grade of ball bearing grease. Then replace the set screws.

(2) Adjustments.

(a) Tightening the Belt.

1 The belt tension and the center distance are adjusted by moving the motor in or out along the motor bracket. Tightening the socket head cap screws which serve as the motor mount pivot bolts will lock the motor in position. These should be loosened when adjusting the belt tension and to provide slack for shifting the belt.

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2 Proper belt tension is obtained by loosening the cap screw and pulling the motor firmly toward the operator. Do not over-tighten the belt, as it reduces its life, and does not increase the capacity of the belt to transmit power. The belt is properly tensioned when the belt may be deflected about an inch midway between the two sheaves.

(b) *Shifting the Belt.* The belt may be shifted from one set of steps to another by pushing the motor forward or by tilting it upward, so as to reduce the center distance between the sheaves.

(c) *Alignment of the Belt.* To obtain full power from the motor, it is important that the belt run straight, thus preventing it from binding against the sides of the V's. The steps of the sheaves should be in line, allowing the belt to run without distortion. If a belt does not run straight, correct it by shifting either the motor sheave or the worm sheave in or out along the spindle.

(d) *Positioning for Angular Fork.* The normal position of the motor spindle is parallel with the worm spindle. For angular adjustment with the belt-driven heads, the motor is tilted to obtain parallelism with the head spindle. To adjust the motor in the tilted position, loosen the two cap screws on the motor mount bracket sufficiently to allow one cap screw to slide in the curved slot. When the motor is positioned, these screws should be retightened.

(e) *Shifting Position of the Sheaves.* Both the worm and motor sheaves are held in position by two socket head set screws. Both of these set screws should be loosened before attempting to shift the position of the sheaves.

(f) *Lead Screw Backlash.*

1 If backlash develops, it may be removed either by eliminating the end play of the lead screw in the cap, or by adjusting the fit up on the lead screw bushing.

2 A threaded retainer collar is located inside the graduated collar just below the ball crank handle. This threaded collar governs the

tightness or preload on the lead screw thrust bearings. To remove end play between the cap and the lead screw, tighten the threaded retainer collar until a slight binding in the bearings is felt. Then lock the threaded collar with the set screw.

3 The bronze lead screw threaded bushings control end play between the lead screw and the main housing. The lower bushing is normally adjusted by turning it to the left, after the set screws which lock the bushing in place is released. Turn the bushing until a slight binding begins on the lead screw.

4 If the threads become worn after extended rough usage, then adjust the lead screw. This is accomplished by turning it to the right on the opposite sides of the threads, which might bring them into use and restore them to their original tightness and smoothness.

5 If the bushing seats before sufficient adjustment is accomplished, scribe a reference line on the bushing and the surrounding casting. Remove the lead screw, then remove the lower bushing, file or grind from 1/32 to 1/16 inch from the inner end, and return the bushing to its original place, lining up the threads by means of the reference line. Replace the lead screw. The bushing is now fully adjustable in both directions.

(g) *Adjusting the Bearings - Removing End Play.*

1 The bearings are held in position and adjusted for end play by the bearing retainers.

2 Worm bearings are correctly adjusted when they allow .004 inch to .006 inch end play in the worm at room temperature and when a 50 pound end thrust is applied to the worm. Overtightening the bearing will cause them to heat and may cause eventual permanent damage.

3 End play in the main spindle is adjusted by the front bearing retainer. Proper end play is obtained by tightening the retainer until the bearings bind slightly while the spindle is turned lightly by hand. The retainer is then backed off just enough to free the bearing rotation.

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(h) *Replacing the Oil Seals.*

1 The openings in the bearing retainers through which the spindle pass are closed with the molded plastic seals. If it is necessary to replace one, only that bearing retainer containing the seal should be removed.

2 The seals are pressed into the retainers by hand and can easily be lifted out or installed. Care should be exercised when returning the retainer to its original position so the seal edges are not damaged.

(i) *Replacing the Gear or Main Spindle Bearings.* Due to the close precision fits maintained, it is recommended that the main housing assembly be removed and returned to the factory when replacements in the assembly are needed. Replacements, however, can be manufactured where precision equipment is available.

(j) *Removing Main Housing from the Frame.* To remove the main housing from the frame, remove the four button head cap screws. Then turn the lead screw to the right and move the Main Housing to its lowest position. Continue turning the lead screw until the cap is raised free of the guide posts. The housing may then be lifted off from the posts.

(k) *Universal Head Main Spindle Adjustment.*

1 Both bearing retainers position the driven gear at its correct mounting distance, and maintains the preload on the main spindle bearings. The rear retainer should not be removed unless the gear needs re-positioning.

2 If the gear needs re-positioning, return the head, if at all practicable, to the factory for correction. If unable to return it, exercise care to insure that the forward, or inner tips of the teeth are the proper distance from the center line of the driving gear. This dimension is .8065/.8060 inch. The front retainer may be turned to increase or decrease the preload.

(1) *Universal Head Gear Adjustment.*

1 The backlash of the universal head gears should be between .002 and .004 inches.

2 Backlash may be adjusted by turning the drive spindle assembly (which consists of all parts contained by the bearing seat insert). The bearing seat insert is locked in position by a dog-point set screw. Loosen this set screw. The bearing seat insert has right hand threads and the backlash is reduced by turning it to the right. Care should be taken not to loosen the drive gear bearing retainer as this will disrupt the preload on the drive spindle bearings. When the gears are properly adjusted, the action of the gears meshing together will be so smooth that no gear contacting will be felt when turning either spindle by hand.

k. *Safety Precautions.* Although accidents resulting from milling machine operations are few in number, they are usually severe.

(1) The greatest hazard of milling machine operations is contact with the revolving milling cutter. Loose or torn clothing should not be worn when operating the milling machine. Chips should be removed from the workpiece with a brush.

(2) Flying chips are dangerous. Wear goggles or a face shield to prevent eye or face injuries.

(3) Do not attempt to tighten arbor nuts using machine power.

(4) Never adjust the workpiece or work-mounting devices when the machine is operating.

(5) When using a cutting oil, prevent splashing by use of appropriate splash pans. Cutting oil on the floor can cause a slippery condition that could result in injury to the operator or other machinists.

5. Conclusion

This task discussed the operation and set up of the toolpost grinder, metal cutting lathe fixture, and the milling, grinding, drilling, and slotting attachments to include lubrication and adjustments. In task three, thread forms and uses will be discussed.

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 3

LESSON 1

THE LATHE USES AND SAFETY; USES, REPAIR, AND
ADJUSTMENT OF LATHE ATTACHMENTS; AND VARIOUS
THREAD FORMS, USES, CALCULATIONS, AND
MACHINING TECHNIQUES

TASK 3. Describe the various threads forms, uses, calculations, and machining techniques.

CONDITIONS

Within a self-study environment and given the subcourse text, without assistance.

STANDARDS

Within two hours

REFERENCES

No supplementary references are needed for this task.

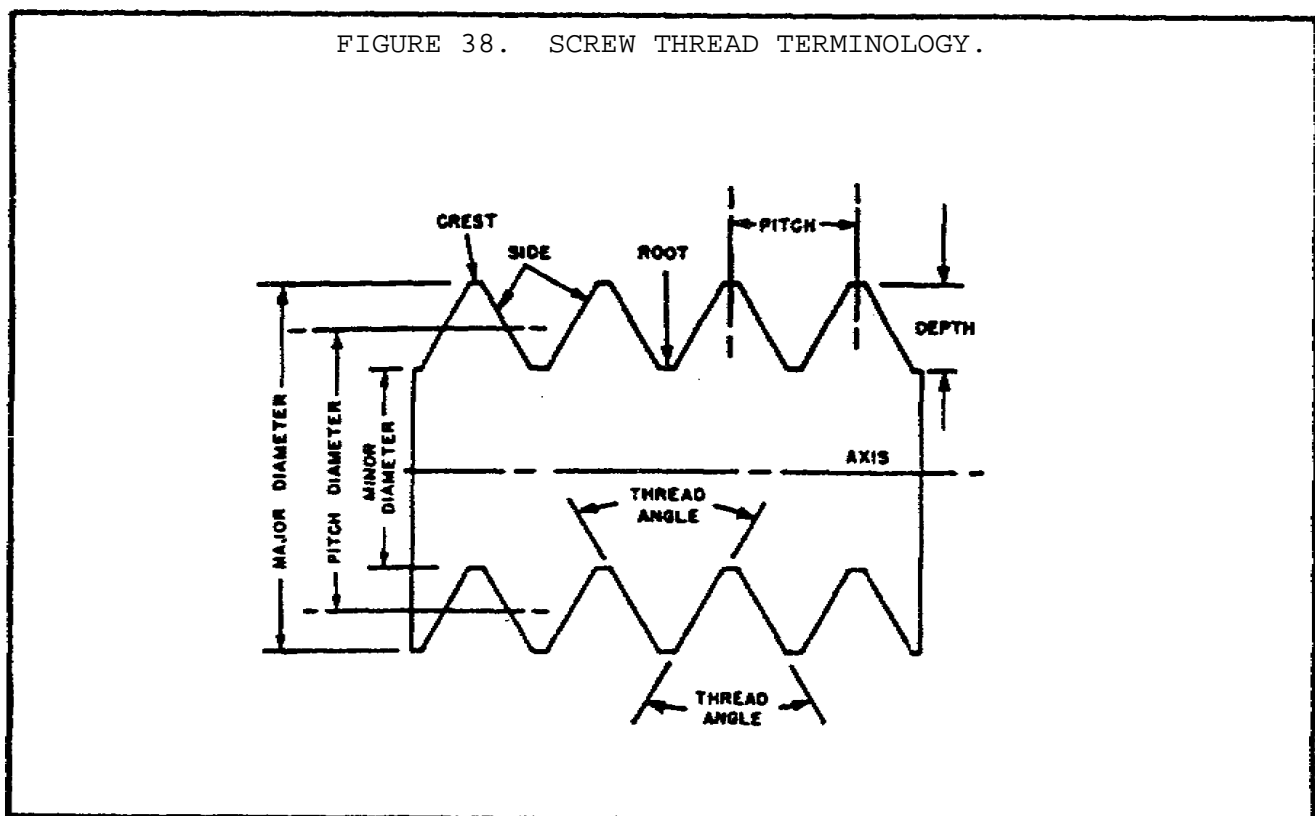
1. Introduction

There are numerous mechanical devices used in modern technology to transmit motion, force, and to fasten components together. One of these devices is the screw thread. Screw threads are made in various forms, such as V-form threads, Acme threads, and Square threads. Each of these thread forms is used for specific purposes. The V-form threads are commonly used on fastening devices such as bolts and nuts as well as on machine parts. Acme threads are generally used for transmitting motion, such as between the lead screw and lathe carriage. Square threads are used to increase mechanical advantage and to provide good clamping ability as in the screw jack or vise screw. Each of these screw forms will be further discussed in this task.

2. Screw Thread Cutting.

a. *General.* A thread is a uniform helical groove cut on or in a cylinder or cone. Thread cutting on a lathe is one of the most exacting lathe operations. It requires a thorough knowledge of the principles and procedures of thread cutting. It ties together a number of operations and dimensions in such a way that accuracy must be maintained to achieve a proper working thread. Before attempting such operations, the operator should have knowledge of the fundamental principles of threads and the types in general use.

b. *Screw Thread Terminology.* The common terms (figure 38) and definitions given below are used in screw thread work and will be used when discussing threads and thread cutting.

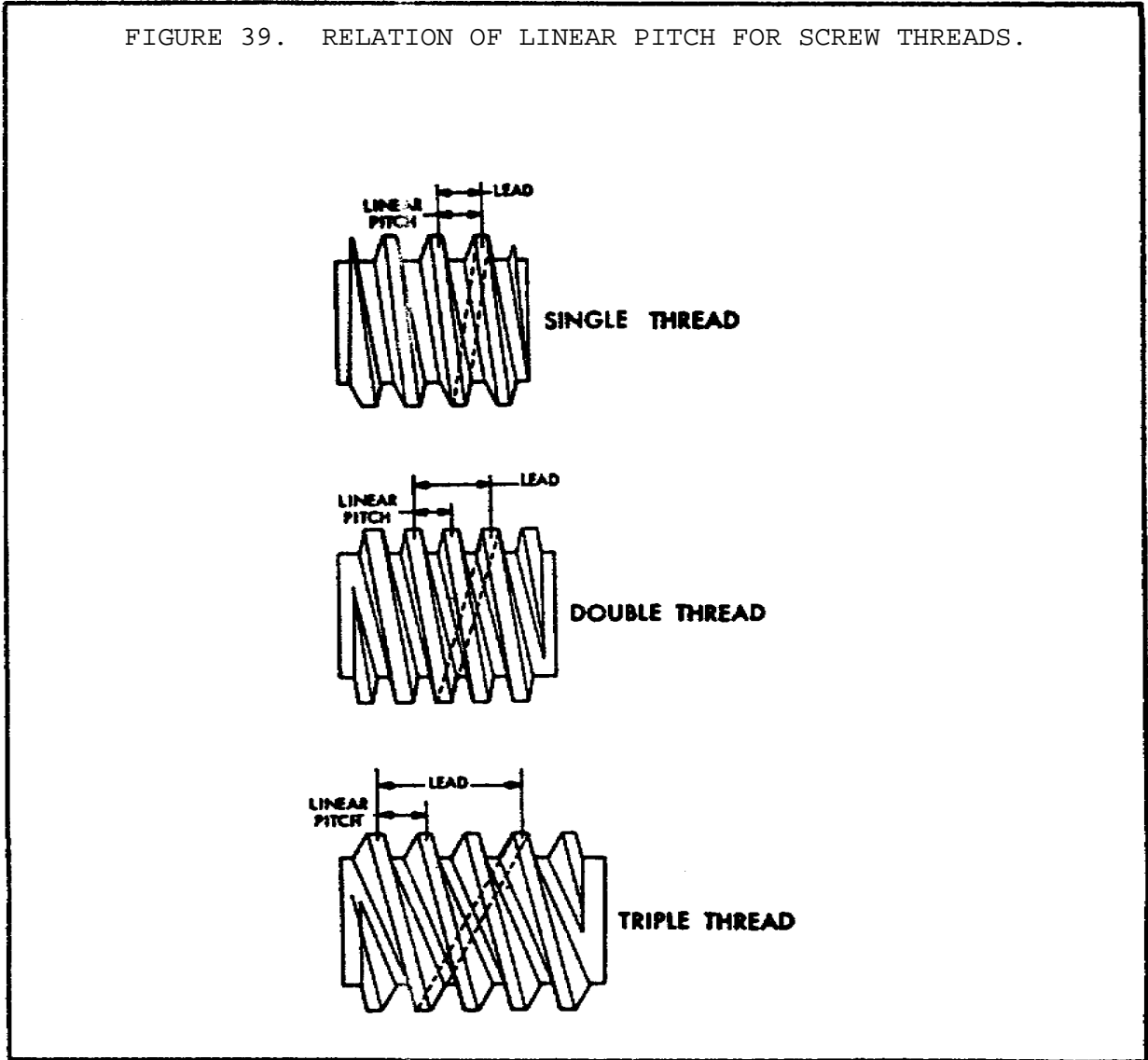


(1) *External or Male Thread.* A thread on the outside of a cylinder or cone.

(2) *Internal or Female Thread.* A thread on the inside of a hollow cylinder or bore.

(3) *Pitch (P).* The distance from a given point on one thread to a similar point on a thread next to it, measured parallel to the axis of the cylinder. The pitch in inches is equal to one divided by the number of threads per inch.

(4) *Lead*. The distance a screw thread advances axially in one complete revolution. On a single-thread screw, the lead is equal to the pitch. On a double-thread screw, the lead is equal to twice the pitch, and on a triple-thread screw, the lead is equal to three, times the pitch (figure 39).



(5) *Crest* (also called "flat"). The top or the outer surface of the thread joining the two sides.

(6) *Root*. The bottom or inner surface joining the sides of two adjacent threads.

(7) *Side*. The side of a thread is the surface which connects the crest and the root.

(8) *Thread Angle*. The angle between the sides of the adjacent threads, measured in an axial plane. For most V-threads, the angle is fixed at 60°.

(9) *Depth*. The depth of the thread is the distance between the crest and the root of a thread, measured perpendicular to the axis.

(10) *Major Diameter (D)*. The major diameter is the largest diameter of a screw thread.

(11) *Minor Diameter (K)*. The minor diameter is the smallest diameter of a screw thread.

(12) *Pitch Diameter*. The pitch diameter is the diameter of an imaginary cylinder formed where the width of the groove is equal to one-half of the pitch. This is the critical dimension of threading as the fit of the thread is determined by the pitch diameter.

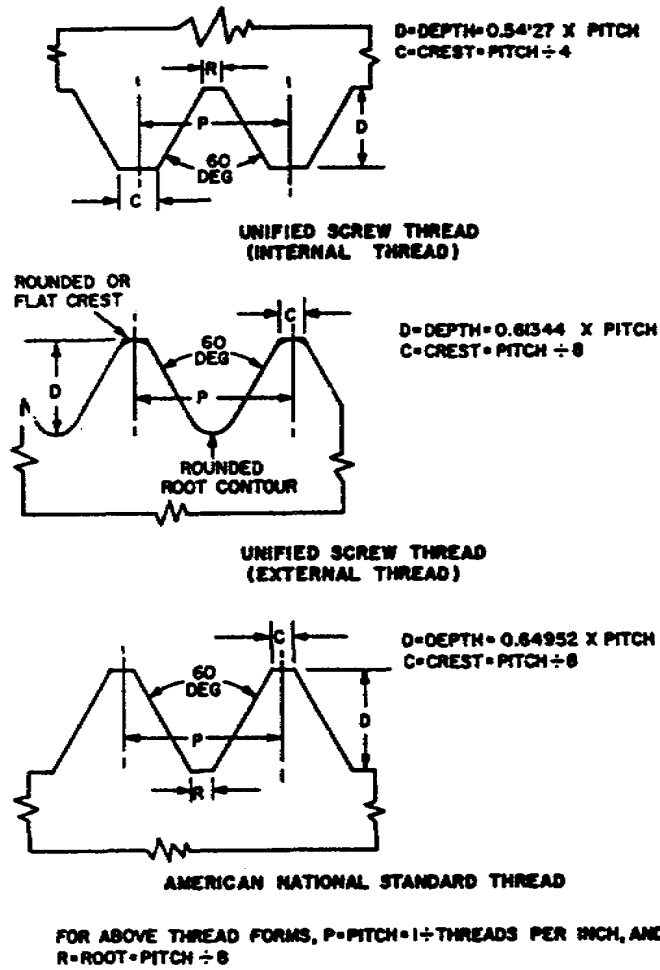
(13) *Number of Threads Per Inch*. The number of threads per inch may be counted by placing a rule against the threaded parts and counting the number of pitches in 1 inch. A second method is to use the screw pitch gage. This method is especially suitable for checking the finer pitches of the screw threads.

c. *Screw Thread Forms*. The most commonly used thread forms are discussed below. Of these threads, the Unified screw thread and the American (National) Standard thread are the most widely required for locking devices. The Acme, square, and 290 worm threads are the most common used for devices which function to transmit motion.

(1) *Unified Screw Thread*. The Unified screw thread (figure 40 on the following page) is the newest of standard thread forms, being acceptable for interchangeable parts by the United States, Great Britain, and Canada. The Unified thread is a variation of the American (National) Standard thread form, having an included thread angle of 60°. On external threads of the unified form, the root is rounded and the crest is optionally rounded or left flat; in the United States, the flat crest is preferred. The internal thread of the Unified form is like the American (National) thread form but is not cut as deep, leaving a crest of one-fourth the pitch instead of one-eighth the pitch.

The pitches, basic dimensions, and tolerances for sizes of 1/4 inch and larger are basically the same for the Unified and American (National) thread forms. The coarse thread series of the Unified system is designated UNC and the fine thread series UNF.

FIGURE 40. UNIFIED AND AMERICAN (NATIONAL) STANDARD SCREW THREADS.



(2) *American (National) Standard Thread.*

(a) The American (National) Standard thread form is being replaced by the Unified screw thread form. It is still in use and is interchangeable with the Unified system.

(b) The American (National) Standard thread form is used in five series of pitches as follows:

- 1 National Fine (NF) (formerly the SAE Standard screw thread).
- 2 National 8-Pitch.
- 3 National 12-Pitch.
- 4 National 16-Pitch.
- 5 National Course (NC) (formerly the USS screw thread).

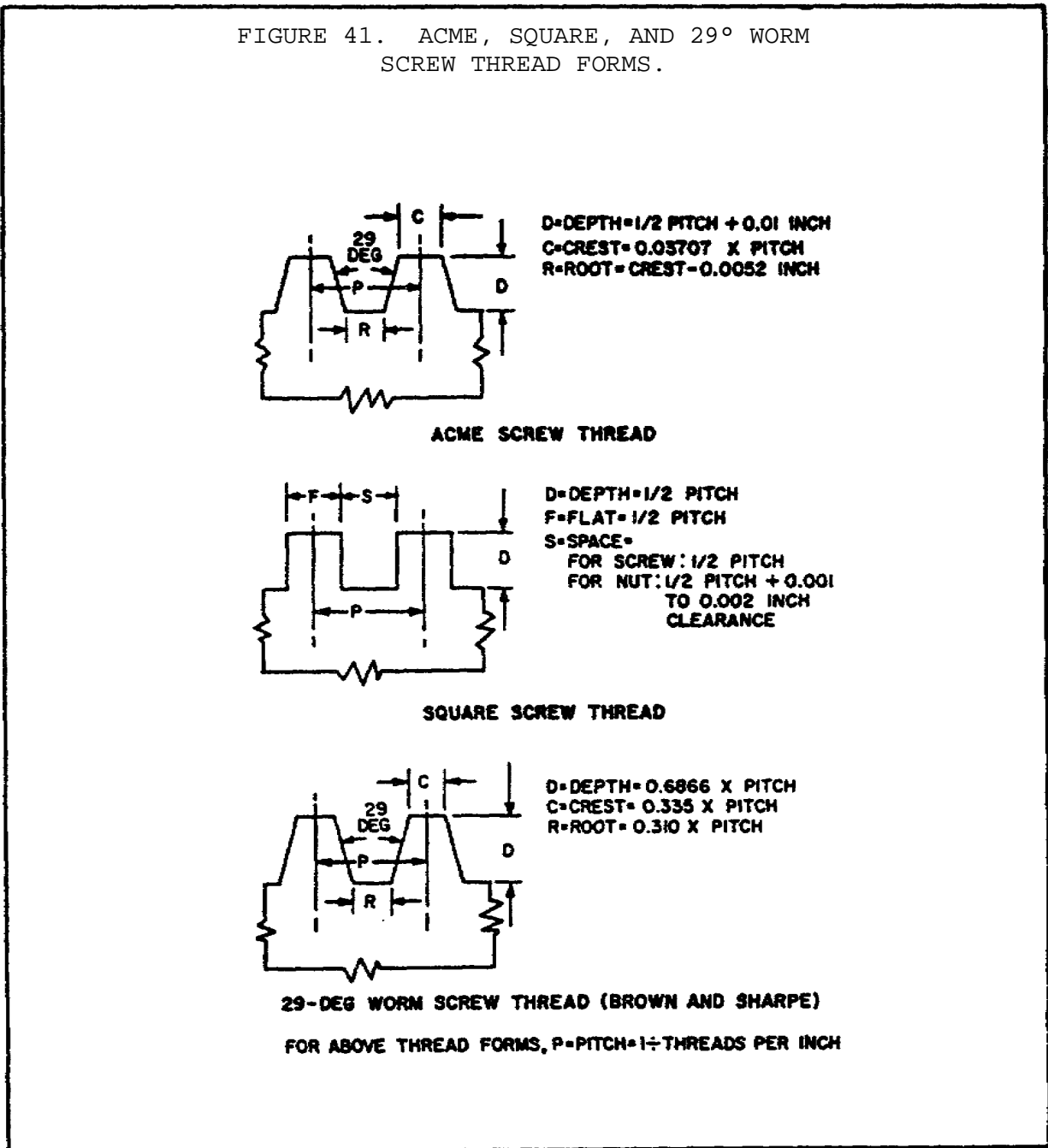
In the coarse and fine series, the number of threads per inch decreases as the diameters increase. These series are intended for general use. Eight-pitch is used bolts, cylinder head studs, high-pressure pipe flanges, and so on. Twelve-pitch is used in modern machine and boiler construction for thin nuts, shafts, and sleeves. Sixteen-pitch is intended for adjusting collars, bearing retaining nuts, or any part requiring a fine thread.

(c) Tables listing general dimensions for the Unified system and the American (National) system are listed in the appropriate technical manuals.

(3) *SAE Extra Fine Threads.* The SAE Extra Fine series has many more threads per inch for a given diameter than any series of the American (National) Standard. The form of thread is the same as the American (National) Standard. These small threads are used in thin metal where the length of thread engagement is small, in cases where close adjustment is required, and where vibration is great. It is designated EF (Extra Fine).

(4) *Acme Screw Thread.* The Acme screw thread form (figure 41 on the following page) is classified as a power-transmitting type of thread. This is because the 29° included threaded angle at which its sides are established reduces the amount of friction when matching parts are under load. Because the root and crest are wide, this thread form is strong and capable of carrying a heavy load. The Acme thread form is especially suitable

for the lathe lead screws and similar power transmitting uses.



(5) *Twenty-Nine Degree Worm Screw Thread.* The 29° worm screw thread and the Acme thread are similar in that they both have an included angle of 29° (figure 41). However, these thread forms should not be confused since they are different in the depth of thread and in the width of the crest and root.

(6) *Square Screw Thread*. Because of their design and strength, square screw threads are used for vise screws, jack screws, and other devices where maximum transmission of power is needed. All surfaces of the square thread are square with each other and the sides are perpendicular to the center axis of the threaded part. Because the contact areas are relatively small and do not wedge, friction between the matching threads is reduced to a minimum under heavy pressure.

d. *Thread Fit and Designations*.

(1) *Thread Fit*.

(a) The Unified and American (National) Standard thread forms designate classifications for fit to insure that mated threaded parts fit to the tolerances specified.

(b) The Unified screw thread form specifies several classes of threads which are classes 1A, 2A, 3A for screws or external threaded parts, and 1B, 2B, and 3B for nuts or internal threaded parts. Classes 1A and 1B are for a loose fit where quick assembly and rapid production are important and shake or play is not objectionable. Classes 2A and 2B provide a small amount of play to prevent galling and seizure during assembly and use, and sufficient clearance for some plating. Classes 2A and 2B are recommended for standard practice in making commercial screws, bolts, and nuts. Classes 3A and 3B have no allowance, and 75 percent of the tolerance of classes 2A and 2B. A screw and nut in this class may vary from a fit having no play to one with a small amount of play. Only high grade products are held to class 3 specifications.

(c) Four distinct classes of screw thread fits between mating threads (as between bolt and nut) have been designated for the American (National) Standard screw thread form. Fit is defined as "the relation between two mating parts with reference to ease of assembly." These four fits are produced by the application and by the tolerances which are listed in the standards. The four fits are described as follows:

1 Class 1 Fit. This fit is recommended only for screw thread work where clearance between the mating parts is essential for rapid assembly and where shake or play is not objectional.

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2 *Class 2 Fit.* This fit represents a high quality of commercial thread product, and is interchangeable screw thread work.

3 *Class 3 Fit.* This fit represents an exceptional high quality of commercially threaded product and is recommended only in cases where the high cost of precision tools and continual checking are warranted.

4 *Class 4 Fit.* This fit is intended to meet very unusual requirements more exacting than those for which class 3 is intended. It is a selective fit if the initial assembly by hand is required. It is not, as yet, adaptable to quantity production.

(2) *Thread Designations.* In general, screw thread designations give the screw number (or diameter) first, then the initial letter of the series, NC (National coarse), UNF (Unified fine), NS (National special), etc., followed by the class of fit. If a thread is a left-hand, the letters LH follow the fit. An example of designations is as follows:

```
Major diameter of thread
.   Number of threads per inch
.   .   Thread series symbols
.   .   .   Class of thread .
.   .   .   .   .----External thread
.   .   .   .   .   Left-hand
.   .   .   .   .
3/4 10  UNC 2   A   LH
```

Two samples and explanations of thread designations are as follows:

(a) No. 12 (0.216) --24 NC-3. This is a number 12 (0.216 inch diameter) thread, 24 National coarse threads per inch, and a Class 3 fit.

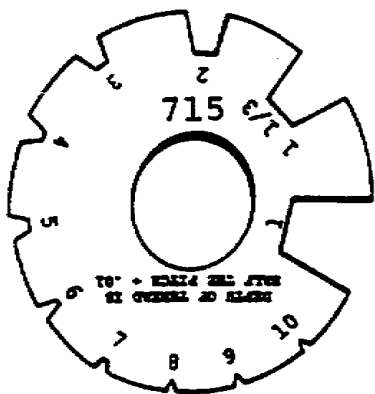
(b) 1/4-28UNF-2A LH. This is a 1/4 inch diameter thread, 28 Unified fine threads per inch, left hand thread, and a Class 2A fit.

e. *Thread Cutter Bits and Cutters.*

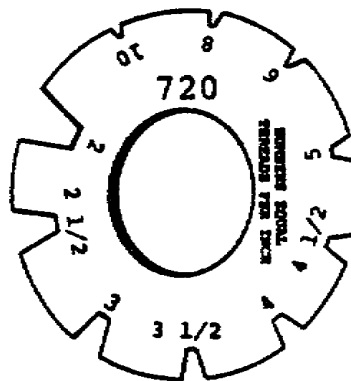
(1) The basic forms of thread cutting bits and cutters were given in the first part of the lesson.

(2) It should be noted that these tools are intended for cutting sharp V-threads with a 60° thread angle. For cutting threads to the Unified or American (National) Standard form, it is necessary to grind the point of the cutter bit to the shape of the thread root. In the case of the American (National) Standard thread, a flat should be carefully ground at the point of the bit, perpendicular to the center line of the 60° thread angle. For the Unified thread, the end of the bit should be ground with the required radius for external threads. In both cases, the tool should be ground to the angle specified by the pitch of the thread (figure 42).

FIGURE 42. THREAD CUTTING GAGES.



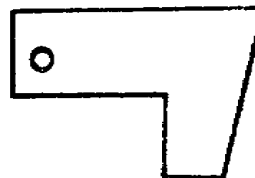
ACME THREAD CUTTING TOOL GAGE



29-DEG WORM THREAD CUTTING TOOL GAGE



60-DEG ANGLE CENTER GAGE



29-DEG ANGLE SETTING GAGE



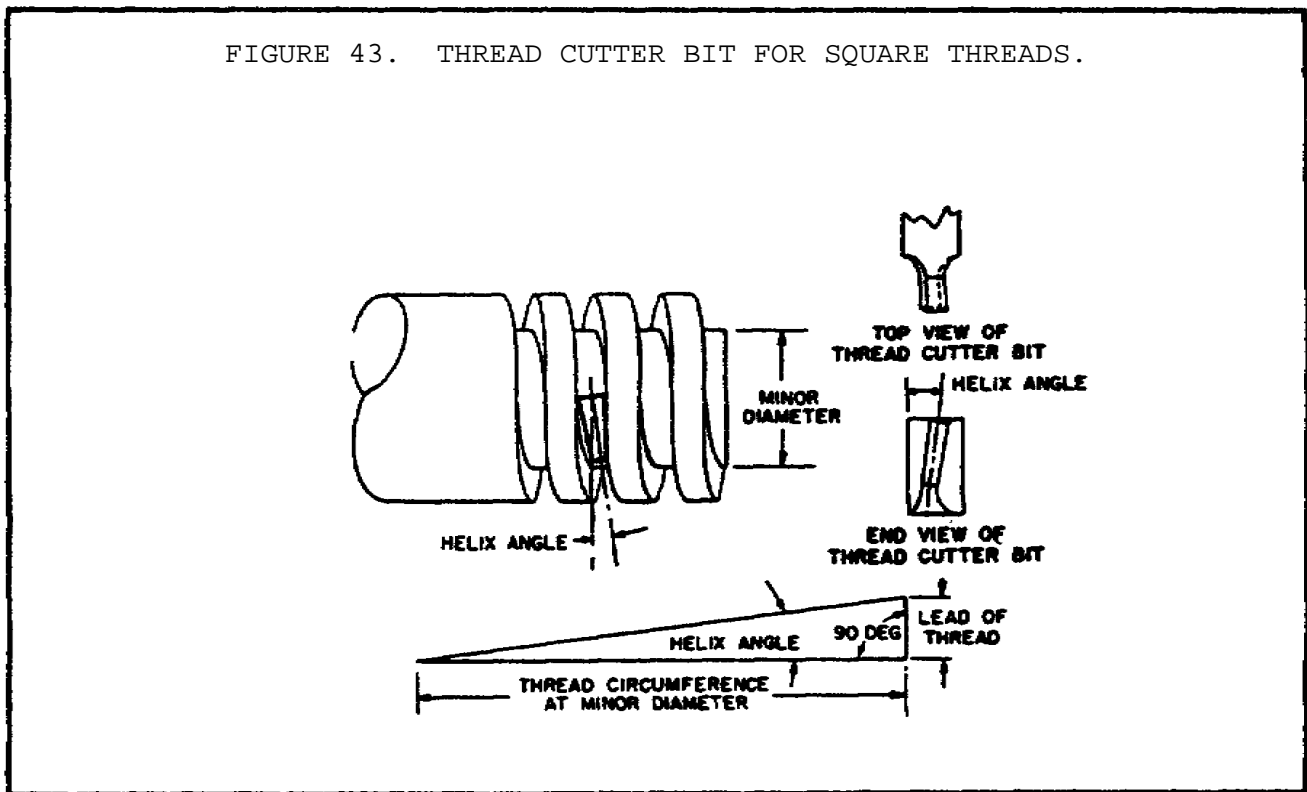
(3) For Acme and 29° wormscrew threads, the cutter bit must be ground to form a point angle of 29°. Side clearances must be sufficient to prevent rubbing on threads of steep pitch. The end of the bit is then ground to a flat which agrees with the root for the specific pitch being cut. Thread

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cutting tool gages (figure 42 on the previous page) are available to simplify the procedure and make computations unnecessary.

(4) To cut square threads, a special thread cutter bit is required.

(a) Before the square thread cutter bit can be ground it is necessary to compute the helix angle of the thread to be cut (figure 43). Compute the helix by drawing a line equal in length to the thread circumference at its minor diameter (this is accomplished by multiplying the minor diameter by 3.1416 (π)). Next, draw a line perpendicular to and at one end of the first line, equal to its length to the lead of the thread. If the screw is to have a single thread, the lead will be equal to the pitch. Connect the ends of the angle so formed to obtain the helix angle.



(b) The tool bit should be ground to the helix angle (figure 43) and the clearance angles for the sides should be within the helix angle. Note that the sides are also ground in toward the shank to provide additional clearance.

(c) The end of the tool (figure 43) should be ground flat, the flat being equal to one-half the

pitch of the thread to produce flats and spaces on the threaded part.

f. *Position of the Cutter Bit for Use.*

(1) The thread cutter bit must be placed exactly on line horizontally with the axis of the workpiece. This is especially important for thread cutter bits since a slight variation in the vertical position of the bit will change the thread angle being cut.

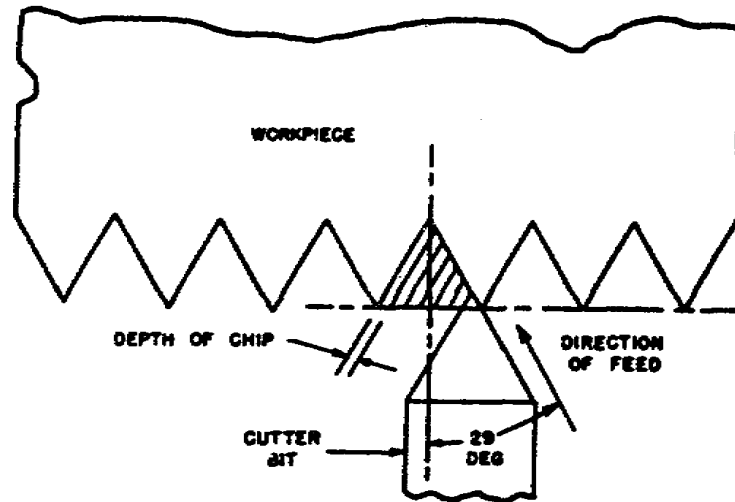
(2) The thread cutter bit must be positioned so that the centerline of the thread angle that is ground on the bit is exactly perpendicular to the axis of the workpiece. The easiest way to make this alignment is by the use of a center gage (figure 42 on page 111). The center gage will permit checking the point angle at the same time as the alignment is being effected. The center gage is placed against the workpiece, and the cutter bit is adjusted on the toolpost so that its point fits snugly in the 60° angle notch of the center gage (figure 44 on the following page).

g. *Setting Lathe Thread Cutting Mechanism for Proper Feed.*

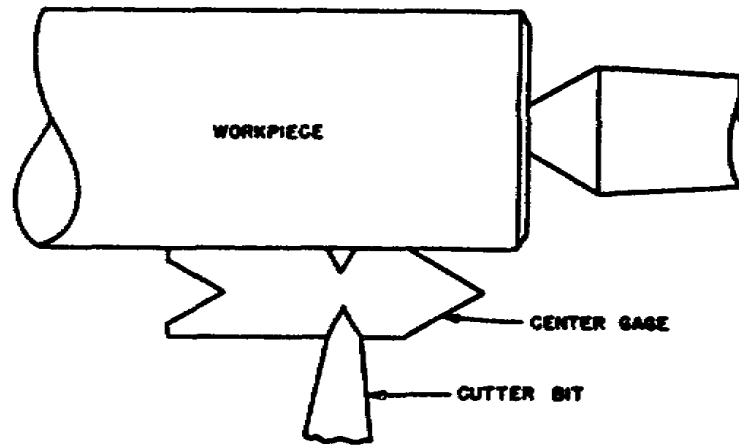
(1) *General.* In cutting threads on a lathe, the pitch of the thread or the number of threads per inch obtained is determined by the speed ratio of the headstock spindle and the lead screw which drives the carriage. Lathes that are equipped for thread cutting have gear arrangements for varying the speed of the lead screw. Most modern lathes have a quick-change gearbox for varying the lead screw to the spindle ratio, but many older lathes, modern inexpensive lathes, and special lathes come equipped with standard change gears which must be arranged by computation to achieve the desired speed ratio.

(2) *Quick-Change Gearbox.* For lathes equipped with quick-change gearboxes, the operator need only follow the instructions on the direction plates of the lathe to set the proper feed to produce the desired number of threads per inch. Once set to a specific number of threads per inch, the spindle speed can be varied depending upon the material being cut and the size of the workpiece, without affecting the threads per inch.

FIGURE 44. SETTING UP CUTTER BIT FOR
THREAD CUTTING OPERATIONS.



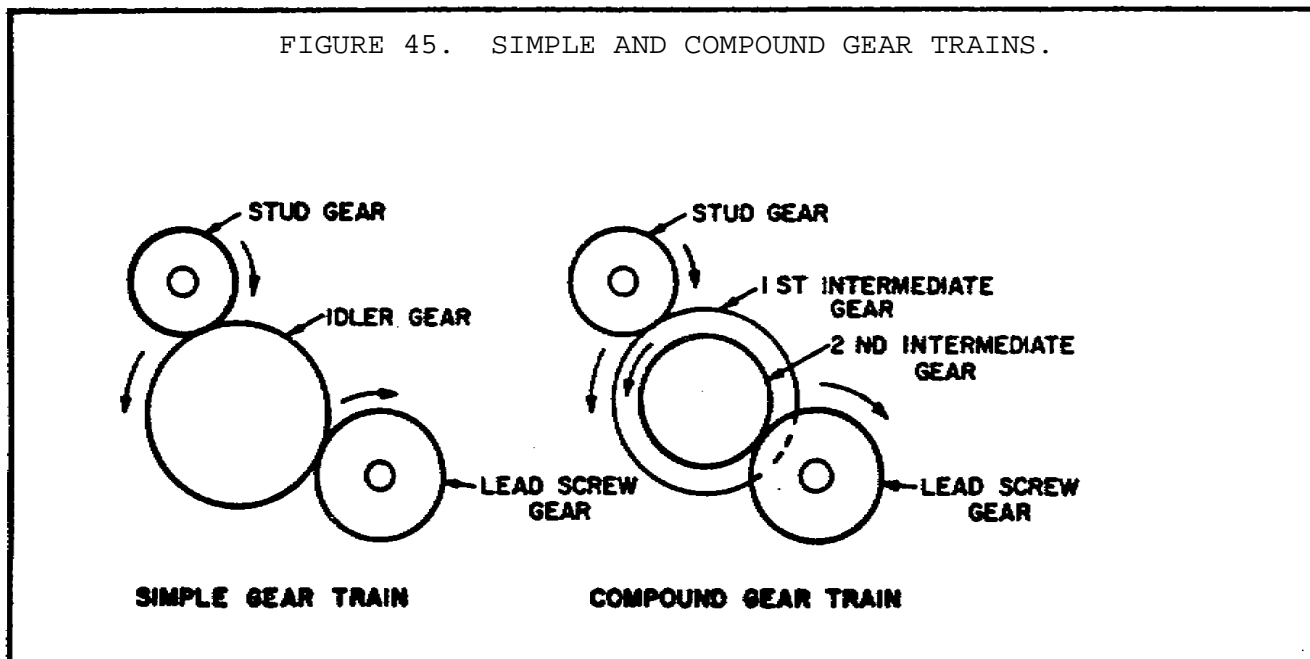
THREAD CUTTING WITH COMPOUND REST
SET AT 29-DEGREE ANGLE



USING CENTER GAGE TO SET CUTTER BIT

(3) *Standard-Change Gears.* Lathes equipped with standard-change gears require that the operator be familiar with the methods of selecting the proper gears to produce the desired thread pitch in case the manufacturer supplied gear tables are missing. On most lathes with standard change gears, the gears may be arranged in a simple gear train or in a compound gear train.

FIGURE 45. SIMPLE AND COMPOUND GEAR TRAINS.

(a) *Simple Gear Train* (figure 45).

1 The basic gears which control the ratio between the spindle speed and the lead screw speed are the stud gear and the lead screw gear. The stud gear mounts to a shaft which revolves at the same speed as the spindle and, therefore, can be considered in this discussion as representing spindle speed in revolutions per minute. The lead screw gear is usually connected directly to the lead screw and, therefore, moves at the same speed as the lead screw. In a simple gear train, the stud gear and the lead screw gear are meshed together or coupled by an idler gear. If the idler gear is used, it can be of any size or number of teeth convenient for coupling since it only transmits motion from one gear to the other and does not affect the ratio of the stud or the lead screw gears.

2 The threads per inch of the lead screw must be known to compute the gearing for a specific ratio. The rule for determining the number of teeth of the stud gear and the lead screw gear for a simple gear train is as follows: Multiply the number of threads per inch of the lead screw and the number of threads to be cut by a common number. The products will be the number of teeth that the stud gear and the lead screw gear should have, respectively. For example, suppose that a

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machinist wants to cut a screw with 10 threads per inch on a lathe having a lead screw with 4 threads per inch. The procedure would be to multiply 10 and 4 by any convenient number, say 6. Then, $6 \times 4 = 24$ and $6 \times 10 = 60$. The stud gear should have 24 teeth and the lead screw gear should have 60 teeth to produce the desired ratio to cut 10 threads per inch. If gears of 24 and 60 teeth are not available, multiply 10 and 4 by another number until the products coincide with the number of teeth that are on available gears.

3 Whenever the thread to be cut is finer than the thread of the lead screw, the gear with the fewest teeth will be the stud gear. If the thread to be cut is coarser than the lead screw, the gear with the fewest teeth will be the lead screw gear.

(b) *Compound Gear Train.*

1 If the proper ratio between the spindle and the lead screw cannot be obtained by simple gearing, a compound gear train must be used (figure 45 on the previous page). For example, if it is desired to cut 80 threads per inch with a lead screw having 8 threads per inch, and the smallest change gear available has 24 teeth, the lead screw gear must have 240 teeth which would be too large in diameter to fit the lathe. By compounding the gears, it would be possible to cut 80 threads per inch with the gears generally available.

2 In the compound gear train, two intermediate gears replace the idler gear of the simple gear train. The intermediate gears are mounted to the same shaft and are keyed together. The gears driven by the stud gear is known as the first intermediate gear and the gear that drives the lead screw gear is known as the second intermediate gear. An idler gear can be used if necessary in this gear train, but will reverse the direction of the lead screw gear, and make reversal of the stud gear-to-spindle connection necessary.

3 To compute compound gear arrangements, the following rule should be applied: establish the ratio between the number of threads per inch to be cut and the number of threads per inch of the lead screw. Factor each term of the ratio; that is, determine two numbers for each term which, when multiplied by each other, result in the number of the ratio term. The resulting four numbers, when

each are to be multiplied by a convenient number, will be the number of teeth in the four gears; the stud gear and the second intermediate gear representing the smaller term, and the first intermediate gear and the lead screw gear representing the larger term of the ratio.

For example, to cut 80 threads per inch with a lathe having a lead screw of 8 threads per inch, the ratio would be 8:80 (8 units to 80 units). Factoring each term, $8=2 \times 4$ (factors), and $80=8 \times 10$ (factors). Then multiplying 2, 4, 8, and 10 each by a convenient number, say 12, the result is the ratio, 24X48: 96X120. The gearing then must be:

Stud gear-----	24 teeth
First intermediate gear-----	96 teeth
Second intermediate gear-----	48 teeth
Lead screw gear-----	120 teeth

(4) *Engaging the Feed.* The carriage is connected to the lead screw of the lathe for threading operations by engaging the half-nut on the carriage apron with the lead screw. A control is available to reverse the direction of the lead screw, and it should be determined that the screw turns in the direction, for left-hand or right-hand threading, as desired. Feed the cutter bit from right to left to produce a right-hand thread. Feed the cutter bit from left to right to produce a left-hand thread.

h. *Direction of Feed.*

(1) For standard 60° threads of the Sharpe V-type, the American (National) Standard form and the Unified form, the cutter bit should be moved in at an angle of 29° so that the left side of the bit does most of the cutting and a free-curling chip may result. The direction is controlled by setting the compound rest at the 29° angle before adjusting the cutter bit perpendicular to the workpiece axis. The depth of cut is then controlled by the compound rest feed handle.

(2) For Acme and 29° worm threads, the compound rest is set at one-half of the included angle (14 1/2°) and is fed in with the compound rest.

(3) For square threads, the cutter bit is fed into the workpiece at an angle perpendicular to the workpiece axis.

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i. *Thread Cutting Operations.*

(1) Before cutting threads on the workpiece, turn down the the major diameter of the thread to be cut. The workpiece may be set up in a chuck or between centers. If a long thread is to be cut, it is advisable to use a follow rest because thread cutting can place a great strain on the workpiece.

(2) The usual practice in cutting threads is to take a very light cut and then check to see that the lathe has been geared correctly for the right number of threads per inch. If it is correctly geared, continue taking cuts until the thread reaches the depth wanted; in the case of Unified and American (National) Standard threads, this is determined by measuring the pitch diameter of the thread, and in the case of Sharpe V-threads, when the thread becomes pointed.

(3) After each pass of the cutter bit, the operator must move the bit out of engagement with the thread being cut and traverse the carriage and bit back to the beginning of the thread. At the end of each cut, the half-nuts are usually disconnected and the carriage returned to the position of the next cut by hand. Some device must be provided, therefore, to engage the half-nuts for the following cut at a point on the lead screw which will cause the cutter bit to follow the previous cut. If such a device is not available, it is necessary to leave the half-nuts engaged at the end of the cut and return the cutter bit by reversing the lathe.

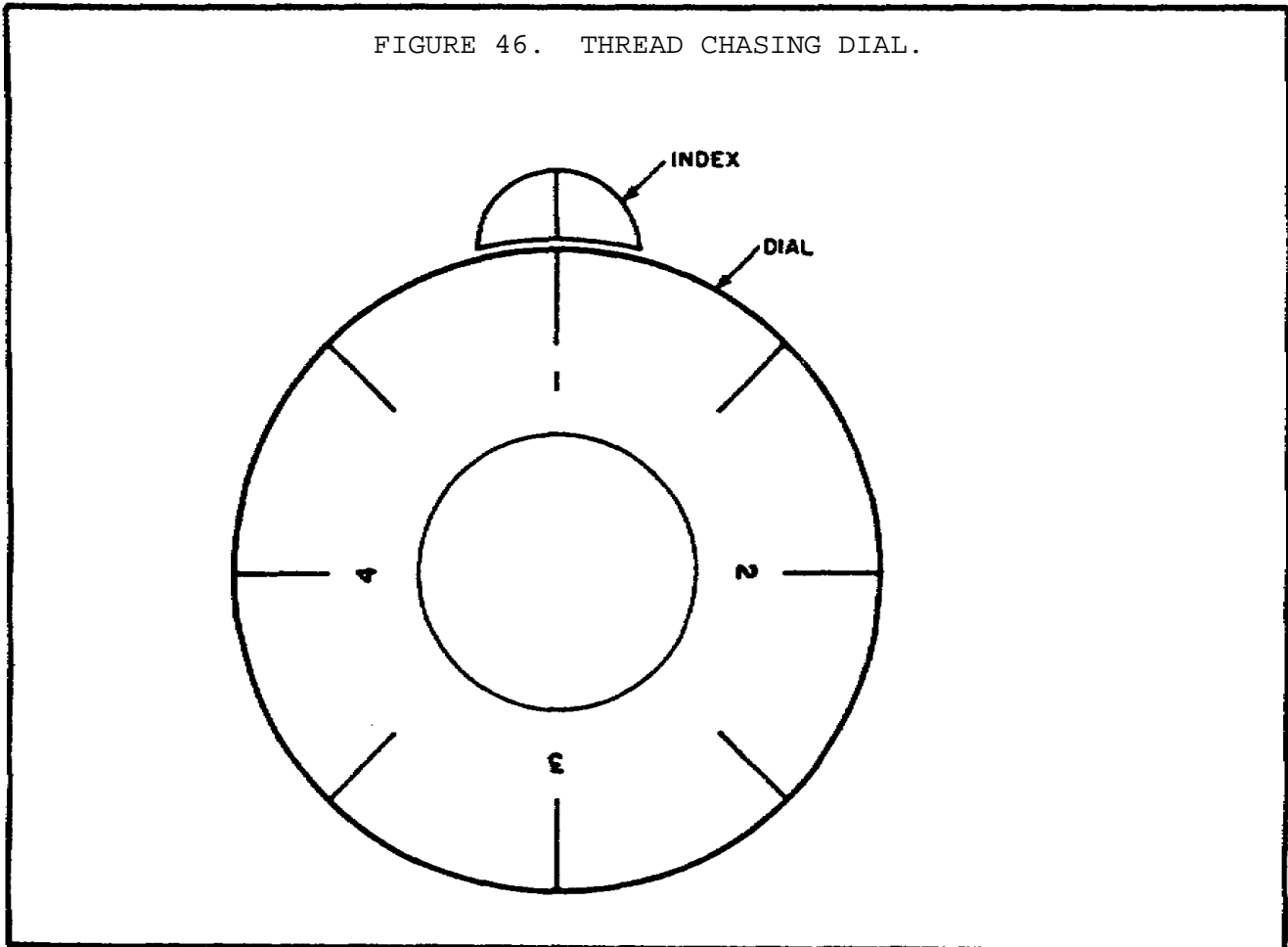
(4) The usual device for accomplishing correct alignment of the cutter bit after the half-nuts have been disengaged is the thread chasing dial (figure 46 on the following page). This device is supplied as standard or optional equipment on all screw cutting lathes. It consists of a worm wheel which meshes with the lead screw, a dial, and a short shaft connecting the worm wheel to the dial.

It is usually mounted to the right side of the carriage apron. The dial is calibrated with four numbered lines and four unnumbered lines between them. To use the thread chasing dial, engage the half-nuts when the dial is lined up for the particular number of threads per inch being cut.

If the number of threads per inch is an even number, the half-nuts can be reengaged for the following cuts when any line on the dial is

opposite the index. When cutting odd number threads, the half-nuts can be reengaged when any numbered line is opposite the index. To cut all threads having a half a thread per inch (such as $1\frac{1}{2}$ threads per inch), the half-nuts can be reengaged when any odd numbered line is opposite the index.

FIGURE 46. THREAD CHASING DIAL.



(5) Some lathes are equipped with a thread chasing stop bolted to the carriage of the lathe. It is used to position the cutting tool.

(6) When the thread is cut, the end of it must be finished in some way. The most common means of finishing the end of the threaded workpiece is with a specially ground bit or a 45° angle chamfer cutting bit. To produce a rounded end, a cutter bit with the desired shape will need to be specially ground for that purpose.

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j. *Taper Screw Threads.* Tapered screw threads or pipe threads can be cut on the lathe by setting the tailstock over or by using a taper attachment. For the National Taper Pipe thread form, the taper is 3/4-inch per foot. Check the thread cutter bit carefully for clearances before cutting since the bit will not be entering the workpiece at right angles to the tapered workpiece surface.

NOTE

In cutting a tapered thread, the cutter bit should be set at right angles to the axis of the workpiece. *Do not set the thread cutter bit at right angles to the taper of the thread.

k. *Measuring External Screw Threads.*

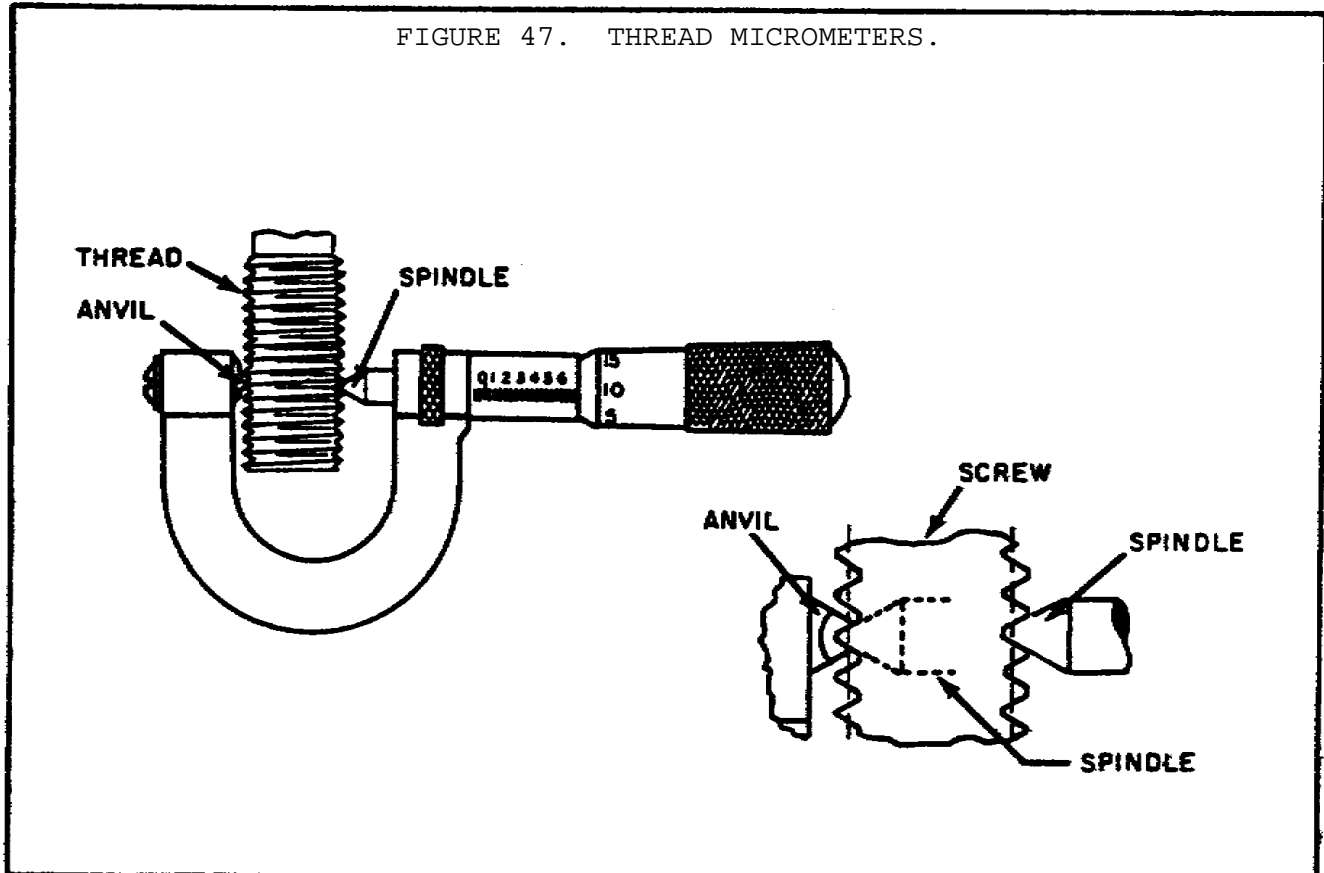
(1) The fit of the thread is determined by the pitch diameter. The pitch diameter is the diameter of the thread at an imaginary point on the thread where the width of the space and the width of the thread is equal. The fact that the mating parts bear on this point or angle of the thread, and not on the top of it, makes the pitch diameter an important dimension to use in measuring screw threads.

(2) Thread micrometers are used to measure or gage the pitch diameter of threads (figure 47 on the following page). They are graduated and read in the same manner as ordinary micrometers. The anvil is V-shaped to fit over the V-thread. The spindle, or movable point, is cone-shaped (pointed to a V) to fit between the threads. Since the anvil and the spindle both contact the sides of the threads, the pitch diameter is gaged and the reading is given on the sleeve and spindle where it can be read by the operator.

(a) Thread micrometers are marked on the frame to specify the pitch diameters which the micrometer is used to measure. One will be marked, for instance, to measure from 8 to 13 threads per inch, while others are marked 14 to 20, 22 to 30, 32 to 40, and so on.

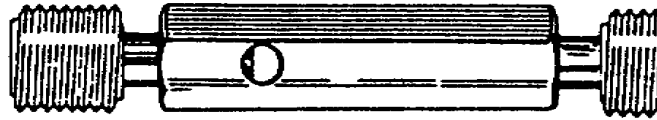
(b) This method of thread inspection is used by the inspection department and the lathe operator.

The procedure used in checking the accuracy of the thread is to first select the proper micrometer, then calculate or select from a table of threads, the correct pitch diameter of the screw. Lastly, fit the thread into the micrometer and take the reading.

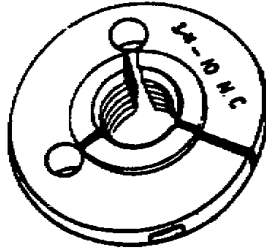


(3) The ring gage (female)(figure 48 on the following page) is screwed onto the thread after it is cut. It checks the completed thread against a standard mating part. By means of a ring gage, the oversize and undersize sections of a thread can be found. Ring gages are made in a variety of sizes and fits. The gage must be carefully chosen to control the desired limits for each thread as determined by the design engineer. Overly close limits mean high manufacturing costs, while overly wide limits cause assembly failures. Gages should be selected in accord with the class of fit for which they are used. For example: if a blueprint calls for 9/16-12UNC-2 thread, it means that the ring gage needed will have a major diameter of 9/16 inch, with 12 threads per inch of the Unified National coarse type, and it should have a class 2 fit.

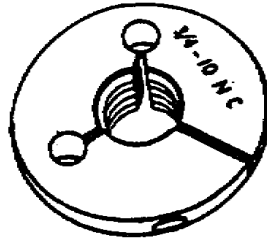
FIGURE 48. THREAD GAGES.



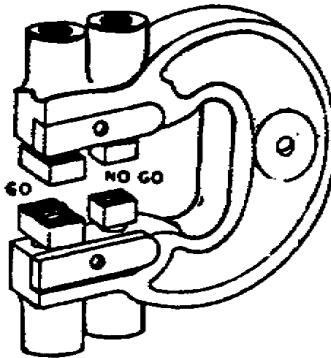
DOUBLE END LIMIT PLUG THREAD GAGE



GO RING GAGE



NO GO RING GAGE



ADJUSTABLE THREAD SNAP GAGE

(4) The three wire method is another method of measuring the pitch diameter of a screw thread. It is considered the best method for extremely accurate measurement. Figure 49 on page 124 shows three wires of the correct diameter placed in threads with the micrometer measuring over them. The pitch diameter can be found by subtracting the wire constant from the measured distance over the wires. It can be readily seen that this method is dependent on the use of the "best" wire for the pitch of the thread. The "best" wire is the size of the wire that touches the thread at the middle of the sloping sides, in other words, at the pitch diameter. A formula by which the proper size of the wire may be found is as follows: Divide the constant 0.57735 by the number of threads per inch to be cut. If, for example, 8 threads per inch have been cut, we would calculate $0.57735/8 =$

0.072. The diameter of the wire to use for measuring an 8-pitch thread is 0.072. The wires used in the three-wire method should be hardened and lapped steel wires. They should be three times as accurate as the accuracy desired in the measurement of the threads. The Bureau of Standards has specified an accuracy of 0.0002 inch. The suggested procedure for measuring threads is as follows:

(a) After the three wires of equal diameter have been selected by using the above formula, they are positioned in the thread grooves, as shown in figure 49 on the following page. The anvil and the spindle of an ordinary micrometer are then placed against the three wires and the reading taken. To determine what the reading of the micrometer should be if a thread is the correct finished size, use the following formula (for measuring Unified National Coarse threads): add three times the diameter of the wire to the diameter of the screw; from the sum, subtract the quotient obtained by dividing the constant 1.5155 by the number of threads per inch. Written concisely, the formula is

$$m = D + 3W - \frac{1.5155}{n}$$

Where m = micrometer measurement over the wires

D = diameter of the thread

n = number of threads per inch

W = diameter of wire used

Example: Determine m (measurement over wires)

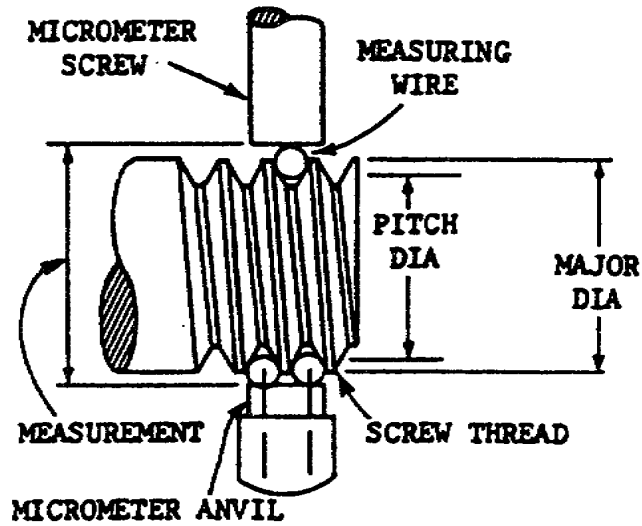
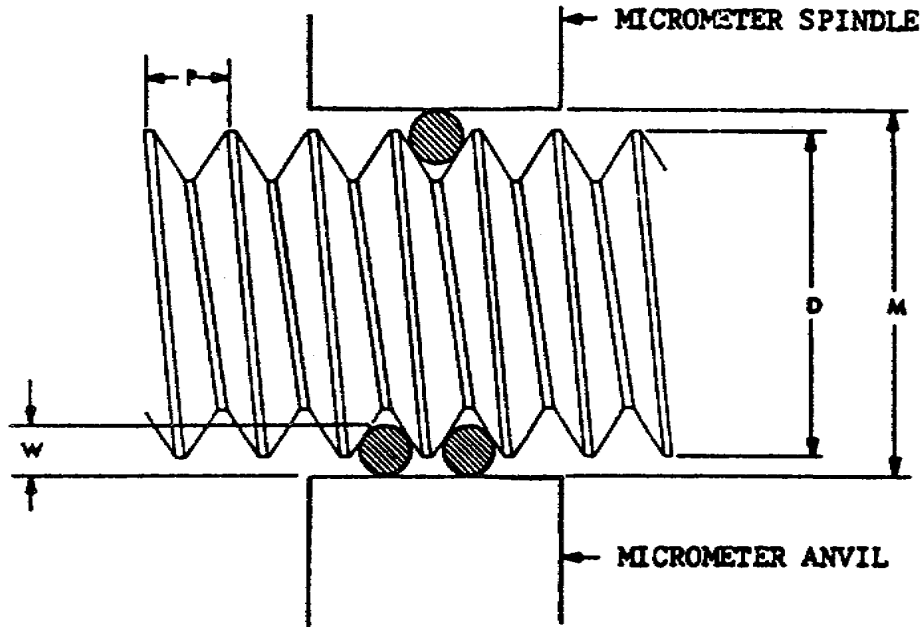
For 1/2 inch, 12 pitch, UNC thread. We would proceed to solve as follows:

Where W = 0.04811 inch

D = 0.500 inch

n = 12

FIGURE 49. THREE WIRE METHODS OF MEASURING THREADS.



$$\begin{aligned} \text{Then } m &= 0.500 + 0.14433 - \frac{1.5155}{12} \\ m &= 0.500 + 0.14433 - 0.1263 \\ m &= 0.500 + 0.01803 \end{aligned}$$

$m = 0.51803$ inch (micrometer measurement)

(b) When measuring a Unified National Fine thread, the same method and formula is used except that the constant is 1.732 instead of 1.5155. Too much pressure should not be applied when measuring over wires.

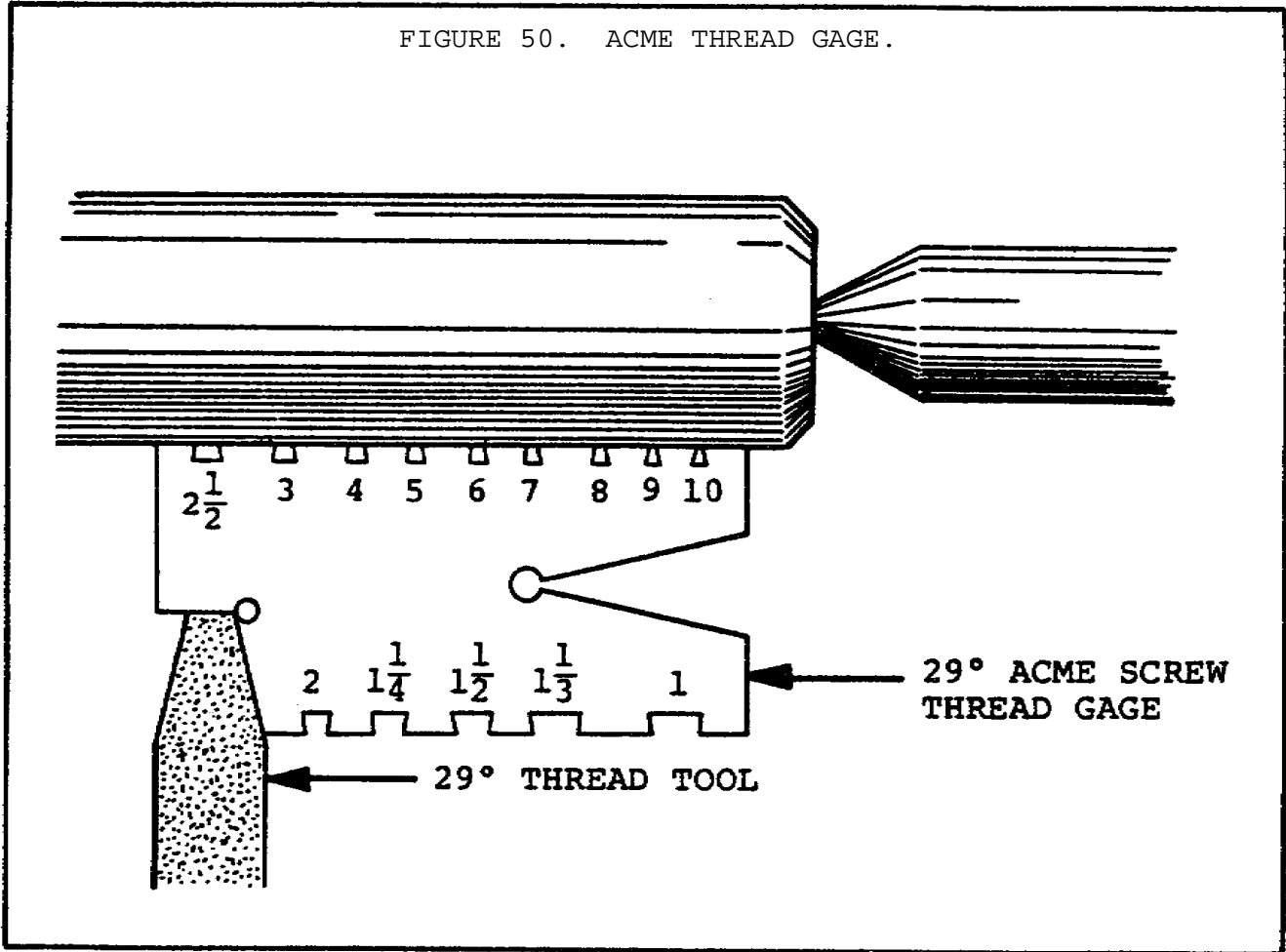
(5) The optical comparator, an instrument based on the magnification principle, is used for obtaining a very accurate comparison between an enlarged template and the threaded part.

(6) The Acme Screw thread was designed to overcome the difficulty of cutting square threads with taps and dies. The Acme thread form is classified as a power-transmitting type of thread. The Acme thread form, when used on lead screws or similar parts, has a distinct advantage. This is because the 29° included angle at which its sides are established (which is almost perpendicular) reduces the amount of friction when matching parts are under the load. Further, because of the wide root and crest, this thread form is strong and capable of carrying a heavy load. The formulas used in determining the depth of Acme and worm threads was previously presented in figure 41 on page 108. The 29° worm and the Acme thread cutting tools are both ground so that their side cutting edges are at a 29° included angle. However, these two threads should not be confused. They are different in the depth of the thread, width of tooth at the top, and width of the tooth at the bottom. The Acme tool has a wider nose, while the 29° worm will cut a deeper thread than the Acme.

1. *Cutting External Acme Threads.*

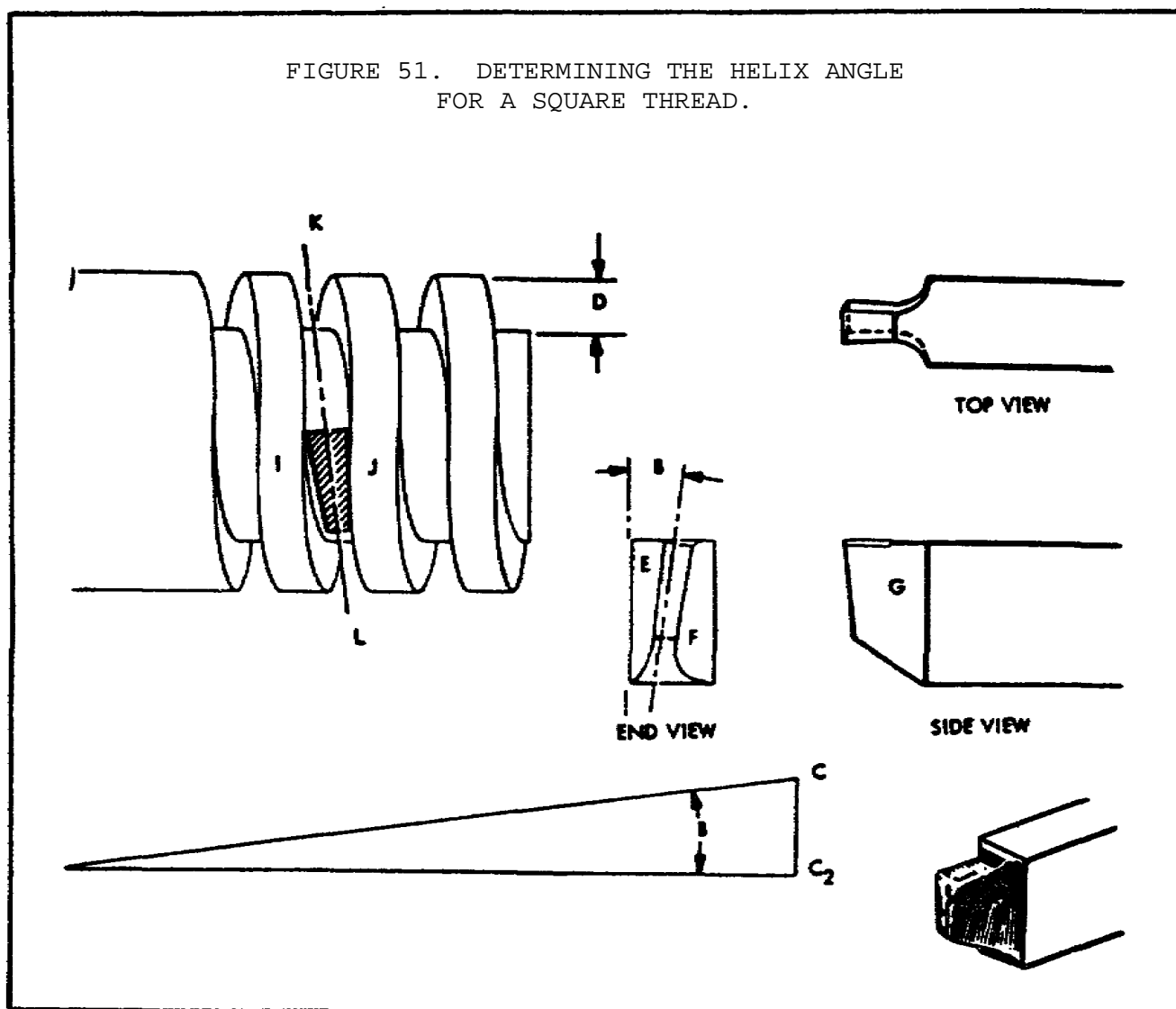
(1) To machine an external Acme thread on the lathe, the first step would be to grind a threading tool to conform to the 29° included angle of the thread. The threading tool is first ground to a point, with the sides of the tool forming the 29° included angle. This angle can be checked by placing the tool in the slot at the right end of the Acme thread gage (figure 50 on the following page). Be sure to grind this tool with sufficient side clearance so that it will cut. Depending upon the number of threads per inch to be cut, the point of the tool is ground flat to fit into the slot in the Acme thread gage that is marked with the number

of threads per inch the tool is to cut. One can see that the size of this flat on the tool point will vary, depending upon the thread per inch to be machined.



(2) After grinding the tool, set the compound rest to one-half the included angle of the thread ($14\ 1/2^\circ$) to the right of the vertical centerline of the machine. Mount the tool in the holder or toolpost so that the top of the tool is on the axis or centerline of the workpiece. The tool is set square to the work, using the thread gage as shown in figure 50. This thread is cut using the compound feed. The depth to which one feeds the compound to obtain the total thread depth is determined by the formula given and illustrated in figure 41 on page 108. The remainder of the Acme thread cutting operation is the same as the V-threading operation previously described. The compound should be fed into the workpiece only at 0.002 inch to 0.003 inch per cut until the desired depth of thread is obtained.

m. *Cutting Square Threads.* Because of their design and strength, square threads are used for vise screws, jackscrews, and other devices where maximum transmission of power is needed. All surfaces of the square thread form are square with each other, and the sides are perpendicular to the center axis of the threaded part (figure 51). The depth, the width of the crest, and the root are of equal dimensions. Because the contact areas are relatively small and do not wedge together, friction between the matching threads is reduced to a minimum. This fact explains why square threads are used for power transmission.



(1) Before the square-thread cutting tool can be ground, it is necessary first to determine the helix angle of the thread. The sides of the tool for cutting the square thread should conform with the helix angle of the thread.

LATHE OPERATIONS - OD1645 - LESSON 1/TASK 3

(2) To determine the helix angle of the square thread (angle B, figure 51 on the previous page) draw the base line AC_2 equal in length to the circumference of the thread to be cut. Draw the line C_2C perpendicular at C_2 and equal in length to the lead of the thread to be cut. Complete the triangle by drawing line AC. Angle B (angle CAC_2) in the triangle is the helix angle of the thread.

(3) The tool bit should be ground at the same angle as angle B. Observe the end view of the cutting tool figure 51. Note that the sides E and F of the tool have been ground to give clearance, while the helix angle has been maintained. The centerline of the tool face is inclined as shown by centerline KL, with clearance at each side as shown at I and J.

(4) For cutting the thread, the cutting edge of the tool should be ground to a width exactly one-half that of the pitch (P). For cutting the nut, it should be from 0.001 to 0.003 of an inch larger to permit a free fit of the nut on the screw.

(5) The cutting of the square thread form presents some difficulty. Although it is square, this thread, like any other progresses in the form of an helix, and thus assumes a slight twist. Some operators prefer to produce this thread in two cuts; the first with a narrow tool to the full depth, and the second with a tool ground to size. This procedure relieves cutting pressure on the tool nose and may prevent springing the work. The cutting operation for square threads differs from cutting threads previously explained in that the compound is set parallel to the axis of the workpiece and feeding is done only with the crossfeed. The crossfeed is fed only 0.002 inch or 0.003 inch per cut. The finished depth of the thread is determined by the following formula:

$$\text{DEPTH} = 1/2 P$$

The width of the tool point is determined by this formula also and will depend upon the number of threads per inch to be machined. It is measured with a micrometer, as square thread gages are not available.

3. Conclusion

This task described the various threads, forms, uses, calculations, and machining techniques. This information will assist you in your future role in the metalworking field.

PRACTICAL EXERCISE 1

1. Instructions

On a plain piece of paper, respond to the requirements listed below.

2. Requirement

Successful completion of this exercise provides an indication of successful progress in the subcourse. Check your answers against those provided on the answer page following the questions.

- a. What do all lathes, (except the turret lathe) have in common?
- b. The engine lathe consists mainly of what components?
- c. Which type of crossfeed does a floor-mounted lathe usually have?
- d. What is a turret lathe extensively used for?
- e. What part of the lathe provides a base for the working parts?
- f. Which type of taper is bored into the tailstock spindle?
- g. When cutting threads, what components in the lathe apron engage and disengage the lead screw?
- h. What are three popular types of toolposts used on lathes?
- i. Which type of metals are alloyed with high speed steel cutter bits?
- j. The quality of work on the lathe depends largely on what part of the cutter bits?
- k. What type cutter bits are tungsten carbide, tantalum carbide, oxide or ceramic?
- l. What type of tool forms a depressed pattern on the workpiece?

- m. What lathe accessory exerts pressure on the workpiece to hold it secure to the headstock or tailstock spindle?
- n. What lathe accessory is the most accurate means of holding small workpieces in the lathe?
- o. What type cutter bit is the proper one used for squaring the shoulder of a workpiece?
- p. What is the toolpost grinding machine used for?
- q. Where is the milling cutting lathe fixture mounted on the lathe?
- r. Backlash is removed from the Metal Cutting Lathe Fixture either by eliminating the end play in the top cap or by _____.
- s. What type of screw is used to mount the versa-mil to the lathe compound?
- t. How is the arbor held in the spindle of the versa-mil?
- u. How is the pitch of a thread measured?
- v. How many pitch series are used in the American (National) Standard thread form?
- w. What point angle must the tool bit be ground to for an Acme thread?

LATHE OPERATIONS - OD1645 - LESSON 1/PE 1

LESSON 1. PRACTICAL EXERCISE - ANSWERS

1. Requirement
 - a. The workpiece is held and rotated around a horizontal axis while being formed to size and shape by a cutting tool.
 - b. Tailstock, carriage, bed, and headstock
 - c. The floor-mounted engine lathe usually has a powered operated crossfeed mechanism.
 - d. A turret lathe is use for high-speed production of duplicate parts.
 - e. Bed and ways
 - f. Morse taper
 - g. Half-nuts
 - h. Standard, castle, and the quick change
 - i. Chomium, vanadium, or molybdenum
 - j. The angles that form the cutting edge.
 - k. Tipped cutter bits
 - l. The knurling tool.
 - m. Chucks
 - n. Collet chuck
 - o. Facing cutter bit
 - p. For cylindrical grinding operations on the lathe.
 - q. On the compound of a conventional lathe.
 - r. Adjusting the fit-up of the lead screw bushing.
 - s. Cap screws
 - t. By a draw bar
 - u. Parallel to the axis of the cylinder.

v. Five

w. 29 degrees

REFERENCES

LATHE OPERATIONS - OD1645 - REFERENCES

REFERENCES

The following documents were used as resource materials in developing this subcourse:

DA Pam 738-750
TM 9-3416-225-12
TM 9-3460-215-10
TM 9-3465-201-10
FM 9-24
NAVEDTRA- 10530-E